Remedial Action Plan for Hamilton Harbour

Environmental Conditions and Problem Definition, March 1989

REMEDIAL ACTION PLAN

FOR

HAMILTON HARBOUR

Stage I Report:

ENVIRONMENTAL CONDITIONS

AND

PROBLEM DEFINITIONS

Ontario Ministry of the Environment
Ontario Ministry of Natural Resources
Ontario Ministry of Agriculture and Food
Environment Canada
Fisheries and Oceans Canada
Royal Botanical Gardens

March, 1989

FOREWORD

This report provides a summary of conditions as they are presently known in Hamilton Harbour, and in Cootes Paradise, a shallow tributary embayment to the Harbour. The Harbour, or as it is sometimes called "the Bay", is a large industrial harbour which is used extensively in conjunction with the iron and steel inudustry. Other major uses of the Harbour are recreational boating and as a receiving waterbody for industrial and municipal waste discharge.

Consultation with the Stakeholders has led to investigation of a wide range of existing and potential water uses within the context of an ecosystem approach. The Stakeholder Group represents environmental groups, industry, municipal, provincial and federal agencies, user groups, and citizens. In addition to its endorsement of the primacy of the Ecosystem Approach, it has also provided guidelines concerning human health, infilling, public access to the shore, land use planning, discharge from the Harbour to Lake Ontario, and the conditions under which waste can be discharged into the Harbour.

While serving as the technical data base for understanding the potential for making water quality and other changes to the Harbour, this report also serves as the Stage I submission to the International Joint Commission, in accordance with the Canada-Ontario committment to the Great Lakes Water Quality Agreement.

Table A indicates the status of beneficial uses (as defined by the Great Lakes Water Quality Agreement Protocol - 1987, Annex 2) for Hamilton Harbour based on technical information, and directed towards the beneficial water uses identified as desirable by the Stakeholders and the public.

Several activities are scheduled for 1989, to assess remedial options for the achievement of water quality or habitat and to support the desired water uses. These activities include, but are not limited to:

- assessment of sediments and their impact in the Harbour.
- investigation of remedial actions to address high concentrations of contaminants in the sediment.
- development of better information on the exchange of water between Hamilton Harbour and Lake Ontario, and its impact on dissolved oxygen and Harbour dilution.
- assessment of the impact on the Harbour of the recent implementation of improved chemical treatment at the Woodward Avenue Sewage Treatment Plant (the largest discharging into the Harbour).
- review of educational, information, planning, and institutional arrangements surrounding the remedial Action Planning and Implementation Process.
- assessment of identified remedial options by the Stakeholder Group, leading to the first report on preferred remedial options.

REMEDIAL ACTION PLAN: TIMETABLE

Activity	Target Completion Date
Phase I, Public Information Program	Completed
Identification of Desired Uses	Completed
Identification of Remedial Options	First phase completed
Selection of Preferred Remedial Options	Third quarter, 1989
Submission of a Draft Plan	Fourth quarter, 1989

TABLE A: Summary of impairment of potential beneficial uses as outlined in Annex 2 of the Great Lakes Water Quality Agreement, and their significance to Hamilton Harbour RAP.

	Use Impairment	Significance to the Hamilton Harbour RAP
i)	Restrictions on fish and wildlife consumption.	Assessing the restrictions on wildlife consumption is not relevant since hunting is not permitted in the area. Although there are currently consumption advisories on five of the twelve fish species listed for the Harbour, four of the species accumulate contaminants Lake-wide because they migrate between the Lake and the Harbour. It is unlikely that reduced loadings to the Harbour alone will result in elimination of fish consumption advisories.
ii)	Tainting of fish and wildlife flavour	No impairment is known to exist for fish. Some fishing occurs in the Harbour but there have been no complaints regarding the tainting of fish flavour. Tainting of wildlife flavour is not relevant for Hamilton Harbour as hunting is not permitted in the area.
iii)	Degradation of fish and wildlife populations	Currently, there are no objectives for desired fish population densities. A reduction in the carp population has been proposed in order to minimize the negative impact on the macrophyte communities. Pike have been stocked in order to increase the population of top predators in the warmwater fishery. Fifty-nine species of fish have been found in the Harbour, 42 of which are reproducing. However, these populations indicate a highly degraded eutrophic system. Two of the four recommended objectives for populations of colonial waterbirds have been exceeded. Populations of double-crested cormorants and black-crowned night herons are slightly below target levels. A reduction in the population of ring-billed gulls has been proposed.

	Use Impairment	Significance to the Hamilton Harbour RAP
iv)	Fish tumours or other deformities.	Liver and skin neoplasms and epidermal papillomas have been reported on several species of fish. Carcinogens are present in Harbour sediments. These sediments have induced liver tumours in fish in laboratory studies. Overall tumour frequency for Harbour fish is similar to the frequency of tumours found in fish from other sites in western Lake Ontario.
v)	Bird or animal deformities or reproduction problems.	To date, control sites have not been selected for bird or animal populations, and selection of sentinel wildlife species has not been made. There are no active bald eagle nests in the area. Reproduction rates for colonial bird populations are considered normal. Bird popluations are being monitored. Higher levels of PCBs, organochlorines, and reproductive anomalies have been observed in snapping turtles in the basin relative to a control site in Algonquin Park. The significance of this information is not understood.
vi)	Degradation of benthos.	The composition of the benthic community is characteristic of a highly eutrophic and toxic environment. Both toxic contaminants in sediment and low oxygen conditions (0.5-1.0 mg/l) in summer contribute to the problem.
vii)	Restrictions on dredging activities.	Hamilton Harbour sediments exceed acceptable limits for open water disposal of dredgeate under Provincial Guidelines. Contaminated sediment, once it is removed, must be placed in a confined disposal facility. Present CDF capacity is only adequate to the year 2000.
viii)	Eutrophication or undesirable algae	Ammonia, phosphorus and nitrogen concentrations exceed the requirements for the growth of algae in the Harbour. The algae present an aesthetic problem as they reduce water clarity and foul beaches and rocks. The ammonia and algae create an oxygen demand that lowers summer hypolimnetic dissolved oxygen to levels averaging 0.5-1.0 mg/l.

	Use impairment	Significance to the Hamilton Harbour RAP
ix)	Restrictions on drinking water consumption, or taste and odour problems.	The drinking water supply for the residents of the Hamilton area and Burlington is Lake Ontario, not the Harbour. No drinking water supply is taken from the Harbour. However, the Harbour water discharges to Lake Ontario through the Ship Canal which is 4 to 5 km from both the Burlington and Hamilton water supply intakes. While no intake to date indicates any problem, diluted discharges from the Harbour have occasionally been detected in the areas of these intakes (1 in 20 observations for each intake) - though not always at the same depth as the intakes.
x)	Beach closings	In the 1930's, on the advice of the Medical Officer of Health, the Hamilton Harbour Commission enacted a by-law prohibiting swimming in the whole Harbour. There may also be some risk to recreational boaters where capsizing may occur. Results of limited sampling carried out in 1988 indicated that remedial programs might be effective in bringing some specific areas of the Harbour within standards. Further investigation is required if swimming is to be considered for the Harbour.
xi)	Degradation of aesthetics.	While oil sheens are observed infrequently, there are periodic occurrences of objectionable turbidity, floating scum, debris, and putrid material. Reduced water clarity persists, due primarily to discharge of suspended solids from tributaries, resuspension by waves and by carp, and to some extent, by algae production.
xii)	Added costs to agriculture or industry.	Hamilton Harbour water is not used for agricultural purposes. Treatment of the Harbour water for industrial use is routine and on-going, and includes the addition of chlorine to rid pipes of algae build-up, travelling screens to remove debris and fish, water strainers to remove suspended material for some particular uses, and bacterial controls for special uses.

	Use Impairment	Significance to the Hamilton Harbour RAP
xiii)	Degradation of phytoplankton and zooplankton populations.	With the exception of one species (Moina brachiata), zooplankton populations are similar in composition to populations in the Bay of Quinte. Abundance is high, reflecting eutrophication and increased productivity. Moina brachiata populations are high in Cootes Paradise and lower in the Harbour. This species is absent from Lake Ontario and from the Bay of Quinte. Earlier studies of the toxicity of Harbour water to phytoplankton and zooplankton were negative. This situation is under review through application of new bioassays.
xiv)	Loss of fish and wildlife habitat.	Fish and wildlife management goals are being developed which will define the amount and quality of physical, chemical, and biological habitat. There are very obvious water-quality-related habitat problems for fish that must be addressed. These include the general loss of submerged vegetation due to water clarity problems as detailed in (xi), and the low oxygen conditions observed in the summer hypolimnion. Other habitat problems relate to loss of marsh areas due to high water levels, poor water quality, and the uprooting activities of carp.

ACKNOWLEDGEMENTS

This report was prepared by the Hamilton Harbour Remedial Action Plan Writing Team. The RAP Team membership currently includes:

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This report is a revised portion of the discussion document Goals, Problems and Options, presented to the Stakeholder Group and the public in the spring of 1988. Many of the revisions embodied in this report are the result of the contributions of Stakeholders, which are gratefully acknowledged.

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EXECUTIVE SUMMARY

A summary of the scientific and technical information available on Hamilton Harbour and areas draining into the Harbour has been prepared with the assistance of several agencies. Building upon the earlier Ministry of Environment 1985 summary report on sediment and water quality (MOE, 1985), recent investigations have updated that material. In addition, substantial new information has been added in regard to fish and wildlife populations and marsh and other habitat considerations in light of the goals stipulated for the Harbour by the Hamilton Harbour Remedial Action Plan Stakeholders.

The substantial improvements in water quality, and in fish and waterbird populations (diversity and abundance) and contaminant content, are documented. These are the results of remedial actions taken to date. The funds expended in this effort have been in the order of $300 million.

Problems remain, largely because the Harbour/Bay receives all industrial and municipal waste, as well as urban and rural runoff from a watershed many times larger than the Harbour itself. Although municipal and industrial point sources presently meet the provincial standards, water quality problems remain - reflecting the total loadings of nutrients and contaminants from the watershed affecting a relatively small body of water.

There remains a substantial water quality stress on this body of water, and serious habitat stresses for fish and wildlife. These environmental problems are summarized in Table B (p. xxiii), and described below.

1. Contamination of bottom sediments is a principal concern. Much of the contamination present is the result of past industrial discharges. Recent deposits are much improved as a result of remedial programs in industry. Yet the most recent deposits and the suspended material in the water column still do not meet the guidelines for open water disposal if dredging is required. Hence, navigation dredging requires a confined disposal facility. The current facility will be filled by the year 2000. Construction of new confined disposal facilities could result in additional loss of shallow water habitat.

   The current guidelines, due to be updated shortly, give little clear advice on remedial action for in situ sediments. Remediation of Windermere Basin has begun through a dredging and confinement program. Following the preliminary protocols for chemical testing and bioassays, a second area of high PAH concentrations and high toxicity near Randle's Reef is actively being assessed for remediation. The PAH source is no longer active and the material resides in a shallow zone where there is greater potential for disturbance by ships or wave action.

   As for the remainder of the Harbour, several remedial measures are under consideration as evidence for the efficacy and environmental impact of each is compiled. Before action is taken on this larger area, however, current source reductions will have to ensure that future deposits meet the new guidelines.

2. **Eutrophication** is severe, with nuisance algal growths, some reduction in water clarity, and dissolved oxygen levels in the hypolimnion in summer hovering around 0.5-1 mg/L. This is a consequence of having two large and two small sewage treatment plants discharging into the Harbour. Phosphorus in combined sewer overflows and in streams add to the problem.

   Low hypolimnetic oxygen concentrations are alleviated somewhat by periodic injections of cold oxygenated water from Lake Ontario which enters the Harbour along the bottom of the Ship Canal - a process controlled by summer heating and winds.

   Reduced phosphorus loadings are required to control excess algal production, but remedial action to improve the dissolved oxygen condition also requires major reductions in oxygen-demanding ammonia loadings.

3. **Contaminants in the water column** have been well addressed in the control programs of the past 20 years. Metal concentrations only occasionally exceed objectives. However, un-ionized ammonia exceeds the objective along the south shore about 50% of the time. The area of non-compliance for ammonia extends over at least one third of the Harbour area in the late winter and spring.

   In the light of some uncertainty about the PCB situation, more extensive and more precise PCB information is required for the water column and for potential sources.

   Spills have been observed to cause fish kills, and efforts must be continued to identify the potential for accidental discharges to the Harbour and to control them.

4. Through bioaccumulation or contact, **fish have accumulated body burdens of contaminants**. In some cases, particularly for the larger older fish, this results in fish consumption advisories stipulated by the health authorities. These centre around mercury, PCB, and Mirex contamination.

   Liver lesions on internal organs and papillomas on the skin are present with frequencies that indicate fish health is not normal. Heavy metals and organic contaminants are both implicated in the lesions. A biological origin (likely virus) is postulated for the papillomas. Both problems may indicate a stressed fish population.

   While specific remedial measures are difficult to target at this time, the general reduction of pollution and habitat stress should be helpful, particularly those measures dealing with toxic contaminants.

5. Widespread **bacterial contamination** violates the criteria for swimming, although the situation has improved over the past 15 years. Programs to disinfect sewage treatment plant effluent (or to improve the efficacy of the disinfection), and to reduce combined sewer overflows, contribute to the improvement. The principal problem will be, however, to deal with the high levels of fecal bacteria during and after the runoff from rainfall. Animal and bird fecal material is washed from the watershed, and since

there is little circulation to move it away from shores in the Harbour, the bacteria levels could remain high for some time.

During dry spells, the levels on the north shore and west end generally meet the criteria, based on the limited data available. The feasibility of ensuring a reasonable beach water quality requires more investigation.

6. Poor water clarity, as well as being less aesthetically pleasing, gives rise to problems for potential swimming areas (guideline is 1.2m Secchi depth, where actual values are usually 0.5 to 1.0m at best), and for the extent of submerged weed habitats, important for fish.

Inorganic suspended material is the major factor affecting the extent of aquatic vegetation. It is caused by erosion, wind-wave action (resuspension), carp activity, algae (see eutrophication) and dissolved material that imparts colour to the water. Measures to deal with erosion, carp populations and phosphorus control are key ingredients for remediation.

7. The warm water fishery of Hamilton Harbour indicates an environmentally stressed community. Although 59 species have been caught in the Harbour, the fishery is dominated by only four species. Carp, white perch, brown bullhead, and gizzard shad make up 70% of the total biomass. Carp, bullhead and shad thrive under conditions of low dissolved oxygen and high concentrations of suspended solids. They can tolerate contaminated sediments and are frequently found in heavily contaminated environments. Their spawning and feeding activities uproot vegetation and resuspend bottom sediments. They prey on juvenile fish and benthos, and eliminate desirable fisheries through predation, competition, and habitat destruction. Populations of carp, bullheads and white perch increase as habitat deteriorates until the balanced fish community collapses into a stable community dominated by pollution tolerant species.

Most of the historic marsh in Hamilton Harbour disappeared as a result of landfilling along the south shore, and cannot be regained. However, the extensive Cootes Paradise and Grindstone marshes disappeared because of the combined effects of sustained high water levels, uprooting of new plants by carp, and poor water clarity. Remedial actions could improve habitat for fisheries along the north and west shores of the Harbour and in Cootes Paradise.

Restructuring fish communities involves habitat development, introductions of desirable species, and removal of problem species. Application of this approach has been successful in contained reservoirs but is very much experimental in the Great Lakes.

8. Wildlife: Harbour At present, colonial waterbird habitat exists at Piers 26 and 27 and at the Hydro Islands. These habitats are in a state of flux. The provincially significant waterbird colonies are the largest or only nesting locations in western Lake Ontario. The complete loss of the herring gull colony would mean the loss of a monitoring tool for organic

contaminants in western Lake Ontario. The colonial waterbirds are probably significant predators of the forage pelagic fish in the Harbour. Rare colonial species have nested in the present habitat locations.

Certain species, particularly the ring-billed gulls, are considered to be a nuisance at the present population levels.

The overall answer to the question of numbers of birds lies in controlling the amount of suitable habitat for each species.

Cootes Paradise The number and diversity of waterbirds and wildlife in Cootes Paradise is limited by the amount of vegetation (marsh) now available. Until the 1940s, the wetland was a well-established, self-sustaining marsh. Though it remains a very important wildlife habitat on the Lake Ontario shoreline, it has been in serious decline for the past 45 years, losing more than 85% of the emergent vegetation cover and over 90% of the submergent plant species.

The problem consists of significant loss or reduction of resident wetland-dependent wildlife, and reduced good quality food supply for migrant waterfowl and other waterbirds, reducing the stopover/staging value of a strategic region of the lower Great Lakes.

The source of the problem lies partly with Spencer Creek. This main tributary has carried increased loadings of suspended solids to Cootes Paradise since the 1940s, reducing the depth and changing the substrate. Wind and waves resuspend the sediment creating highly turbid conditions in the water which in turn reduce light penetration. The introduced carp directly impact the plant community as noted above in #7. The timing of the annual water-level regime of Lake Ontario is "out of synchronization" with the normal growth cycle of aquatic plants, thereby restricting them to small amounts of littoral habitat which fringe the basin. Finally, STP effluent, CSO discharge and watershed inputs (creeks) add nutrients to such an extent that eutrophication occurs.

Institutional Problems

The multiplicity of agencies responsible for, or having a stake in, the outcome of a complete rehabilitation program is daunting. While several formal mechanisms (e.g. environmental assessments) link agencies or the public in dealing with parts of the system, no formal mechanism exists which links these agencies and community interests in a comprehensive way - a way which we are trying to achieve with the Stakeholder Group. Nevertheless, it will be necessary for these groups to work together closely to achieve the multiple uses of the Harbour envisaged in the goals developed by the Hamilton Harbour Stakeholder Group and the public.

The means to achieve this cooperation will necessarily be a major concern for the continuity and effectiveness of the Remedial Action Program.

TABLE B: Summary of environmental problems affecting Hamilton Harbour.

Current Conditions	Impaired Uses	Sources of Problem	Current Information Deficiencies
1. Toxic Contamination in Bottom Sediments - sediments exceed open water disposal guidelines - sediment toxicity and related contaminated concentrations are excessive in about 200 ha. of bottom sediments	- dredging for navigation - benthic invertebrates - fishery - wildlife	- historical input from industry - spills - current contaminant inputs	- quantitative relation between deposition of acceptable sediments and contaminant loadings is unknown - exact consequence of remediation on biota unknown - relative efficacy of various treatment measures unknown
2. Eutrophication - nuisance algal growths - maximum phosphorus concentrations exceed 80 μg/L - summer hypolimnion oxygen levels are as low as 0.5-1 mg/L - summer chlorophyll a concentration in the surface water 27 μg/L - average summer Secchi depths range from 1-1.5 m	- fishery - aesthetics - benthic invertebrates - recreational boating	Phosphorus and ammonia in: - STP effluents - CSO's - industrial effluents - tributary streams - sediment phosphorus reflux - urban runoff	- response of dissolved oxygen to phosphorus and ammonia reductions uncertain - exact loadings from storm events (CSO's and tributary streams) uncertain - confirmation of time for cessation of sediment phosphorus reflux is unknown
3. Toxic Contaminants in the Water Column - un-ionized ammonia concentrations exceed PWQO's about 50% of the time - occasional exceedences of PWQO's have been observed for metals	- fishery	- STP effluents - industrial effluents - CSO's - rainfall - spills	- better PCB information required - contaminant loadings from rainfall and dust fall not adequately quantified - contaminants discharged from CSO's not monitored adequately
4. Contamination of Fish - consumption limitations for 5 of the 12 species listed for the Harbour; one species restricted for consumption of all sizes - consumption limitations are the result of one or more of Mirex, PCB's, and mercury - neoplasms and other lesions have been observed on several species of fish; carcinogens and viruses suspected	- fishery - fish health - human health	Sources uncertain, but may be: - rainfall - sediments - open waters of Lake Ontario	- determining of source of contaminants accumulating in fish is complicated by seasonal movements of the fish between the Harbour and the Lake - link of specific contaminant in a fish to an exact source generally is difficult, requiring difficult judgement about which measure is likely to be effective

Current Conditions	Impaired Uses	Sources of Problem	Current Information Deficiencies
5. Health Risk from Bacterial Contamination			
- mean fecal coliform counts exceed the level set for swimming - previous estimates of total coliforms indicate that the Harbour water exceeds the objective for swimming - some areas meet the criteria occasionally but only during dry spells - concern for possible effects on nearby Lake Ontario beaches	- swimming - water sports	- STP effluents - CSO's - urban runoff - tributary streams	- analysis of conditions for specific proposed swimming sites is required - impact of Harbour bacteria on Lake Ontario bacteria unknown
6. Poor Water Clarity			
- inorganic turbidity reduces light penetration affecting nearshore water clarity and the extent of submerged vegetation required for fish habitat - some of the water clarity problems due to colour in the water	- swimming - fishery - aesthetics	Sources of suspended solids: - streams - STP effluents - CSO's - industrial effluents - resuspension of Harbour sediment by waves and carp	- source of colour unknown - loadings of suspended solids from streams during storms lacks adequate quantification
7. Unbalanced Fish Population			
- 59 species of fish have been found in the Harbour - 70% of biomass in the Harbour and 94% in Cootes Paradise consists of pollution-tolerant carp, gizzard shad, white perch, alewife, and brown bullhead - lack of top predators in the warm water fishery - major losses of fish habitat have taken place through infilling around the Harbour	- fishery - habitat for fish and wildlife - swimming - aesthetics	- introduction of exotic fish species - habitat destruction	- experimental management required to reduce the impact of carp and re-establish a balanced fish community - experimental management required in rehabilitating fish habitat
8. Wildlife			
- numbers of waterbirds are constrained by available habitat - numbers of ring-billed gulls are considered to be excessive - concentration of contaminants in gull eggs, low hatching rates and the incidence of mutants have all declined	- wildlife - aesthetics	- habitat loss due to carp and infilling - see above under #1 and #4	- more extensive information required on animal populations and ducks - experimental management required for ring-bill gull control and creation of suitable habitat for desirable species

I INTRODUCTION

I.1 Hamilton Harbour: An "Area of Concern"

As a component of the overall strategy to address pollution in the Great Lakes, Canadian and U.S. jurisdictions identified 42 Areas of Concern, and reported them to the Water Quality Board of the International Joint Commission (IJC). Areas of Concern are locations where water quality, or sediment and biota contaminant content, do not meet standards. Hamilton Harbour is one of these.

In their 1985 report, the Water Quality Board outlined their reasons for so designating Hamilton Harbour (IJC, 1985):

"IJC Water Quality Board Assessment
NATURE OF PROBLEM (as of June 1985).

Types of Problems	Sources
Conventional Pollutants	Municipal Point Sources
Heavy Metals	Industrial Point Sources
Toxic Organics in Fish	Urban Non-point
Contaminated Sediments	Combined Sewer Overflows
Eutrophication	In-Place Pollutants
Fish Consumption Advisories	
Aesthetics	

Municipal and industrial discharges, urban drainage, sediments, and algal decay increase oxygen demand. This oxygen demand depresses hypolimnetic dissolved oxygen levels, especially in the summer. This, in turn, limits the suitability of the deeper part of the Harbour as a fish habitat.

Aesthetic quality is diminished by poor water clarity and colour, as a result of high levels of suspended solids, chlorophyll, and dissolved organics, thereby deterring broader recreational use of the Harbour.

Significant levels of nutrients, several heavy metals, and PCBs have been detected in the surface sediments from several portions of Hamilton Harbour.

Water quality objectives are exceeded for total dissolved solids, zinc, ammonia, and phosphorus. Iron, cyanide, and phenolics also exceed water quality objectives on occasion, especially adjacent to the steel mills on the south shore.

Levels of trace organics (PCB, PAH), and phenols in fish are under investigation."

I.2 The RAP Process

Prompted by the Ontario Ministry of the Environment report on management options for Hamilton Harbour (MOE, 1985), a separate initiative was undertaken to obtain community concensus on what should be done to complete the rehabilitation of the Harbour.

This effort then came under the auspices of the Remedial Action Plan Program, led in Canada by the Canada-Ontario Agreement Review Board. The Review Board supports the development of Remedial Action Plans through financial support in public consultation, facilitation of interagency participation, and redirection of the research and engineering expertise of federal and provincial agencies towards analysis and development of solutions for problems associated with the RAP areas.

The fact that a new process for developing an Action Plan has been initiated does not imply that nothing has been done in the past to control pollution in the Harbour. Industry and municipal governments have spent approximately $300 million on pollution abatement programs. By 1989 the major industries discharging to the Harbour will be meeting all the requirements of the current Ontario Ministry of the Environment control orders. The Provincial government has also put into effect new programs, like the Municipal Industrial Strategy for Abatement (MISA), that will have beneficial effects on toxic contaminant control.

There is still a need to consider what additional measures should be taken to restore beneficial uses - uses which are still impaired in spite of existing effluent controls. These existing effluent standards may not be adequate to protect the Harbour from the sum of all loadings of nutrients and chemicals and their interactions. Nor do current effluent standards address historical deposits of contaminants in the Harbour.

There are a number of recent reports on water quality in the Harbour that serve as the basis for analysis in this report. Prime among these is the technical summary on Hamilton Harbour conditions published by the OMOE (MOE, 1985). The present analysis has been expanded to include Cootes Paradise, as there are links to both water quality and habitat development for fish and wildlife. And it has expanded on earlier work in its attempt to address more fully the biological aspects of the Harbour.

There are, however, some difficulties in using only the existing information to quantify the impact of some of the major remedial projects that have to be considered. For this reason the Team has also drawn upon recent unpublished work and have identified the need for additional information, which will be reflected in our recommendations for work in the future.

I.2.1 The Role Of The Writing Team

The Writing Team for the Hamilton Harbour Remedial Action Plan (RAP) has been asked by the Canada/Ontario Review Board to address the problems identified by the Water Quality Board of the International Joint Commission and the goals specified by the public. The Plan is to be prepared by the Writing

Team in consultation with the public and the Stakeholders. The Plan, in its final form, should include an analysis of the existing conditions, and an Action Plan to meet specific objectives, including dates and estimated costs. Finally, the Plan must include the design of a monitoring system to ensure that the Action Plan and the expected results are proceeding on schedule.

Our knowledge of the Harbour and of Cootes Paradise continues to grow. Much of the new information coming forward is targeted specifically on questions raised in the development of this Action Plan. The Team will need to regularly consult and incorporate these new data into the Plan as it progresses. And, indeed, the provision of annual reports seems essential throughout the progress of the remedial action.

The Writing Team has also been helped extensively by other staff of the organizations represented on the team. Their assistance is gratefully acknowledged.

I.2.2 Public Consultation

Public consultation is an important element of the process in developing the Remedial Action Plans. It is needed for refinement of the goals and timetables for water quality and ecosystem improvements. As well, it provides a forum for discussion of cross-jurisdictional issues and develops heightened awareness of the overall program.

Two public consultation processes are being employed. Public meetings for the general population of the watershed are open sessions designed to provide the most recent information on the Remedial Action Plan, and to permit formal presentation of briefs from interested groups. Citizens are also asked to submit their views at the meetings or in writing. These briefs and comments have been considered by the Writing Team and the "Stakeholder Group".

The second process has been to establish a "Stakeholder Group" made up of agencies, organizations, institutions, government departments, industries and private citizen groups who make use of, who wish to make use of, or in some manner have jurisdiction over the use of Harbour water. Some 60 potential Stakeholders were interviewed individually, and eventually 49 formed the group (see Appendix D).

During a 2-day workshop in July, 1986, and through subsequent meetings, the Stakeholder Group developed a Stakeholders' Interim Report which summarizes their proposals (Hamilton Harbour Stakeholders, 1986). This report was submitted to the Ministers of the Environment for Canada and Ontario in September 1986, and forms a basic point of reference for the Writing Team.

The development and updating of the Remedial Action Plan will require continuing consultation. The Stakeholder Group has collectively expressed the wish to be a forum for review of matters having a bearing on the remedial actions proposed for the Harbour, both during and after the Plan is established.

The Interim Report of the Stakeholders is a detailed analysis of the present or possible beneficial uses for the Harbour. It describes principles for development of the Remedial Action Plan including the ecosystem approach, human health, public acceptance, and aesthetics. The principle of zero discharge of persistant toxic substances was added after subsequent discussions in January 1987.

The Stakeholders' Interim Report also contains recommendations and general remedial actions for two groups of goals. One set of goals and actions is to permit the current defined uses, including recreational boating, water sports, shipping and navigation, industrial uses, and waste water receiving. Goals and recommendations were also identified for uses that are not presently available to any substantial degree, including fisheries, wildlife appreciation, swimming, and the use of the Harbour as an educational resource. The Writing Team is considering this comprehensive list of beneficial uses in the context of the IJC goals for water quality improvement. The reader is encouraged to consult the full report of the Stakeholders.

I.3 Future of the RAP

This document contains:

(a) a description of the existing environment and summary of problems,
(b) a summary of impaired beneficial uses, and
(c) a description of the causes of the problems.

It does not yet identify jurisdiction and agencies responsible for implementing and regulating remedial measures, nor does it contain a schedule for their implementation and completion. The final Plan will also need to describe a process for maintaining an audit of the implementation of remedial programs and should include the description of a process for tracking the effectiveness of remedial actions.

The Agencies and Stakeholders must review the options and recommend those preferred. This review is scheduled for early 1989. The general public will also be given an opportunity to review the draft Remedial Action Plan (Preferred Options) that results from the Writing Team with advice from the Stakeholders.

Following the development of the Preferred Options report, the Agencies will develop program schedules and funding committments to result in the final Remedial Action Plan. When this is documented, it will be submitted to the IJC as the Stage 2 Report. This report is expected in late 1989 or early 1990.

II DESCRIPTION OF HAMILTON HARBOUR AREA

II.1 Geography and Geology

II.1.1 Geographic Description of the Harbour

Hamilton Harbour is located at the west tip of Lake Ontario (Figure 1). A sandbar separates the Harbour from Lake Ontario and exchange with the Lake is accommodated through the Burlington Ship Canal (820m x 88m x 9.5m). The Harbour is triangular in shape with an east-west axis of 8 km and a north-south axis of 5 km. The surface area of Hamilton Harbour is 2150 hectares. With a mean depth of 13 m and a maximum depth of 26 m, the Harbour has a theoretical hydraulic residence time (ie. volume/inflow) of about 500 days but exchange with Lake Ontario shortens the residence time to an average of only 90 days.

The mouth of Grindstone Creek, in the northwest sector of the Harbour, is an important shallow littoral habitat area. About 17% (380 hectares) of Hamilton Harbour is shallower than six meters (the littoral zone) but approximately 90 hectares are currently colonized by aquatic vegetation due to various physical stresses and poor water clarity.

The pelagic zone occupies 83% of the Harbour area. Due to the morphometry of the Harbour basin, the summer hypolimnion contains 50% of the total volume of water in the Harbour (the total volume is 2.8×10^8 m^3). The hypolimnion is significant in the Harbour because during the summer when stratification becomes established, oxygen exchange with the atmosphere is cut off and the oxygen remaining in the hypolimnion is quickly depleted.

At the far west end of Hamilton Harbour is the Desjardin Canal, which leads to Cootes Paradise (Figure 1). Cootes Paradise has an open-water surface area of 250 hectares, a mean depth of 0.7 m, and a hydraulic residence time of several days depending on the season. The long axes of both Cootes Paradise and Hamilton Harbour are oriented northeast-southwest which is also the predominant axis for the prevailing winds.

Windermere Basin, in the southeast corner of Hamilton Harbour, has a surface area of approximately 40 hectares and a mean depth of 0.7 m (Figure 1).

II.1.2 Historical Changes to the Harbour

The current outlet from the Harbour to Lake Ontario was constructed in 1823. Little change in the shoreline of the Harbour occurred until 1853 when a new outlet, the Desjardin Canal, was constructed from Cootes Paradise to the Harbour. The old channel was filled in to permit railway construction, leaving Mercer's Glen, Long Pond and Sunfish Pond as the only remnants of the original channel. Little filling has been done on the north shore with the exception of the LaSalle Park Pier and the filling of Brants Pond in the northeast corner. The southwest end of the Harbour was modified by railway construction in the late 1800s. Between 1862 and 1926, industrial and port expansion began filling in the extensive marsh habitat on the south shore. By 1959, the south shore

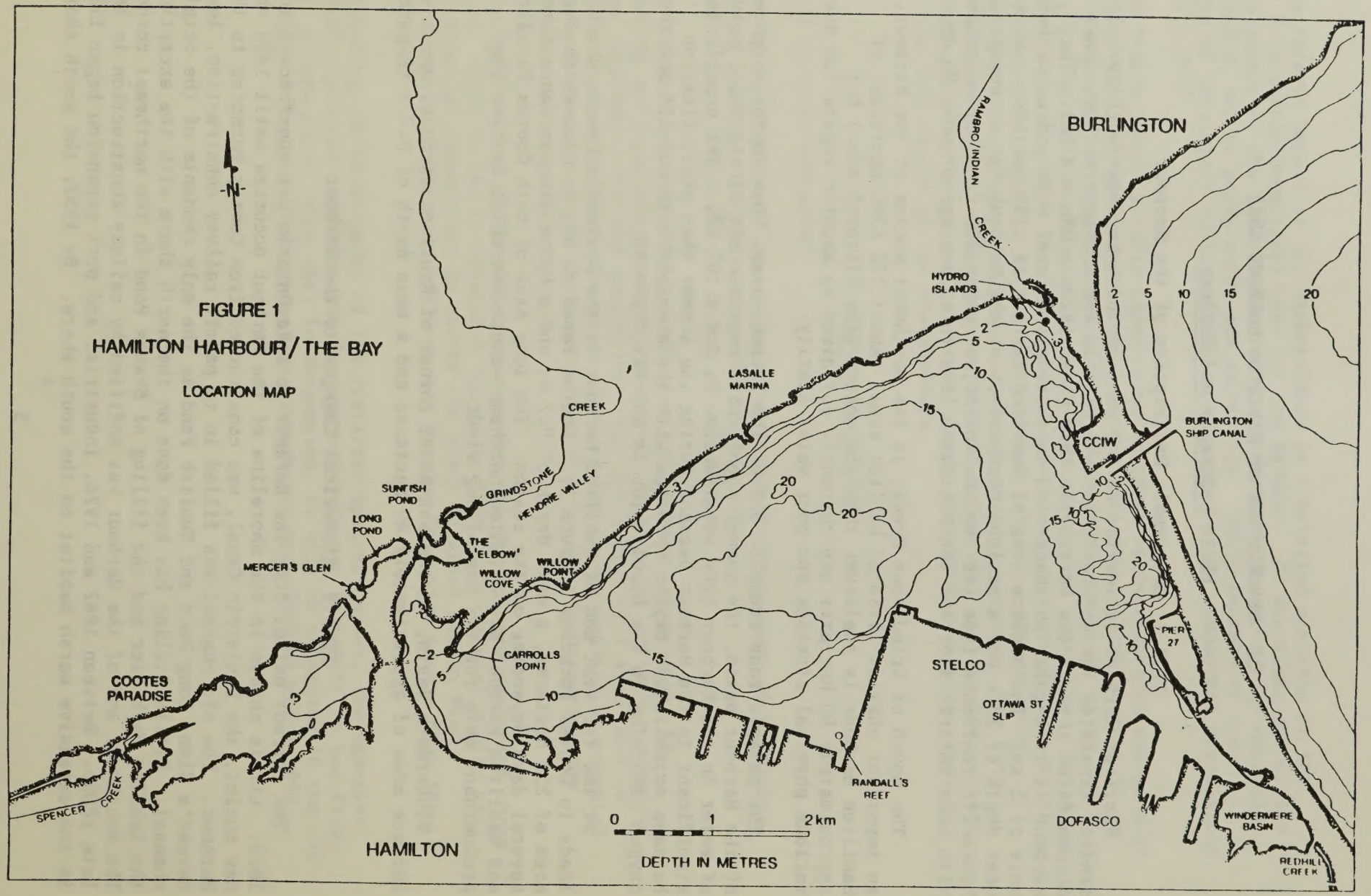


FIGURE 1
HAMILTON HARBOUR/THE BAY
LOCATION MAP
N
BURLINGTON
RAMBRO/INDIAN CREEK
HYDRO ISLANDS
LASALLE MARINA
CCIW
BURLINGTON SHIP CANAL
CREEK
GRINDSTONE
HENDRIE VALLEY
SUNFISH POND
LONG POND
THE 'ELBOW'
MERCER'S GLEN
WILLOW COVE
WILLOW POINT
CARROLLS POINT
COOTES PARADISE
SPENCER CREEK
HAMILTON
STELCO
OTTAWA ST SLIP
RANDALL'S REEF
PIER 27
DOFASCO
WINDERMERE BASIN
REDHILL CREEK
0 1 2 km
DEPTH IN METRES
2 5 10 15 20

marshes had been filled in and Windermere Basin had been created (Figure 1). By 1976, 22 percent of the open water area in the Harbour was lost, relative to 1926. The most serious loss to the Harbour was the extensive marsh littoral area. The current wetland area is estimated to be less than 50 hectares from an historic maximum of approximately 500 hectares. The loss of marsh littoral area has had a profound impact on the fishery and wildlife.

II.1.3 Drainage Basin

The total drainage basin of Hamilton Harbour (including Cootes Paradise) is 49,400 hectares (Figure 2). Cootes Paradise receives runoff from five sub-watersheds for a total sub-basin area of 26,000 hectares. Spencer Creek, with a total area of 17,000 hectares, is the largest sub-watershed in the Cootes Paradise drainage basin. Red Hill Creek (7,190 ha.), Grindstone Creek, Indian Creek/Rambro Diversion, as well as numerous combined sewer water overflows and smaller creeks flow into the Harbour.

II.1.4 Hydrology

Annual precipitation ranges between 65 to 108 cm. The major runoff period is February to April, and the total annual runoff is approximately 1.1 to 2.1 X 10^8 m^3. Creek inflows (Cootes: 60%, Red Hill: 15%, Grindstone: 14%) account for 89% of the natural runoff, with storm water runoff from the cities of Hamilton (4%) and Burlington (7%) accounting for the remainder. Of the 2.6-3.8 x 10^6 m^3/day of water entering the Harbour from all sources, natural runoff accounts for only 2-19%, sewage treatment plants (STPs) account for 7-16%, and Lake Ontario accounts for 72-87%. The water entering the Harbour from the Burlington and Hamilton STPs comes from Lake Ontario by way of the Regional water supply plants. Exchange of Lake Ontario water through the Burlington ship canal dominates the water budget of the Harbour. The result of all these flows in and out of the Harbour is that residence times vary from 73 to 107 days for winter and summer respectively.

II.1.5 Topography of the Watershed

The watershed's topography is characterized by a number of major, natural features which influence drainage and land use patterns. The Niagara Escarpment is the most outstanding physiographic feature of this region (Figure 2). Above the Niagara Escarpment, three major physiographic areas can be identified (the Galt Moraine, the Flamborough Plain and the Haldimand Plain). Two major areas are present below the Niagara Escarpment (the Iroquois Plain and the Dundas Valley).

II.1.6 Geology

The area is one of both glacial and lacustrine deposition, and therefore contains most types of glacial deposits and landforms. The Galt Moraine, drumlin, esker, kame, and outwash-deposit complex occurs in the Town of Flamborough. This moraine is quite stony, with a rough hummock topography. The Flamborough Plain occupies part of the Town of Flamborough, and has shallow deposits above bedrock. The south is characterized by thin lacustrine deposits, while sand and silts occur in the north. These deposits merge with

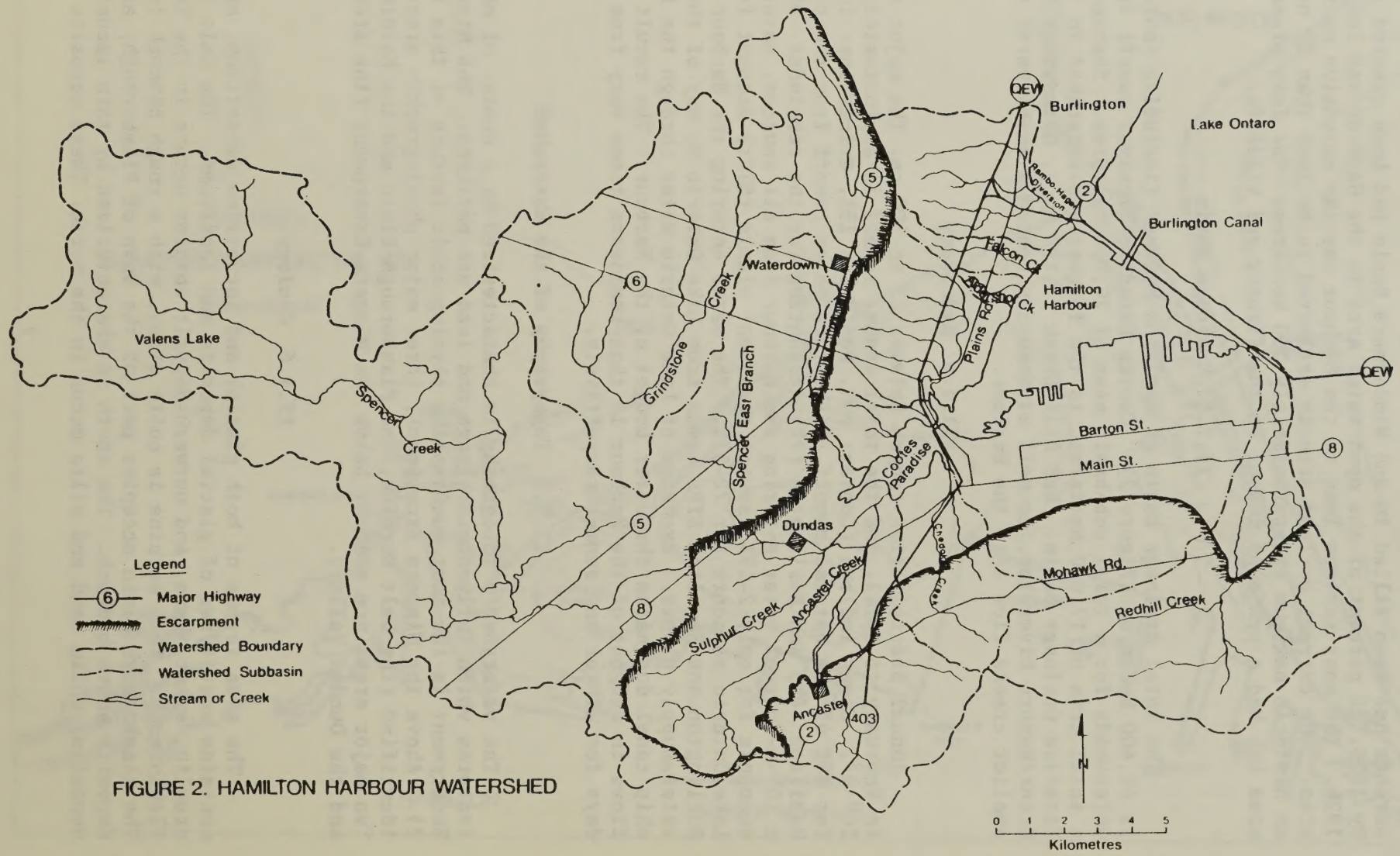


FIGURE 2. HAMILTON HARBOUR WATERSHED

the outwash sand and gravel of the drumlins in the north. The Waterdown and Vineland Moraines can be found at the top of the escarpment. In the township of Glanbrook and parts of the towns of Ancaster and Stoney Creek is the extensive Haldimand clay plain.

The Iroquois Plain extends from Lake Ontario to an elevation of about 100 metres, and consists of weathered red shale overlain by lenses of clay till and lacustrine sand. Between this area and the escarpment is a rolling area dissected by ravines which sometimes extend back into the escarpment. The Dundas Valley is the largest and deepest of such ravines.

The Niagara Escarpment was produced by differential erosion of several rock types. The Queenston formation of red shale, with occasional greenish siltstone bands forms the base of the escarpment. The Cataract and Clinton groups of white and grey sandstones, grey shale and buff dolomite rest upon this Queenston formation and are exposed along the escarpment. Capping the escarpment is resistent dolomite of the Lockport formation.

II.1.7 Soil Types

Many soil types are present in the watershed. The surface textures of the soils include loams such as Burford, Guelph, Jeddo, Lily and Parkhill; silt loams and silty clay loams such as Colwood, Toledo, Lincoln and Morley; sandy loams such as Flamboro, Granby, Grimsby, Jeddo and Springvale; and gravelly loams such as Donnybrook. Well drained soils include Burford, Donnybrook, Guelph, and Grimsby soils; and poorly drained soils include Colwood, Flamboro, Grandby, Jeddo, Lily, Lincoln, Morley and Parkhill soils.

The topography of the soils vary from gently undulating to undulating for the Burford and Grimsby soils to level to depressional for the Colwood, Flamboro, Grandby, Jeddo, Lily, Lincoln, Morley and Parkhill soils. Donnybrook soils are rolling to hilly, and Guelph soils undulating to gently rolling.

II.1.8 Erosion

The combination of soil texture, drainage and topography determines to a great extent the agricultural use of the soils, which in turn determines the potential for soil erosion from agricultural areas. Table 1 illustrates the interaction between soil erosion and soil type, slope and land use for three soil types found in the watershed, using the Universal Soil Loss equation.

Silt loam and silty clay loam soils as well as steep slopes can be very susceptible to erosion. The conventional cultivation of row crops with little soil cover over winter and spring has the potential for increased movement of the soil.

The loss of 3 tonnes/acre of soil is the maximum acceptable level of soil loss, since mineral soils develop at about that rate. However, if the loss of soil is greater than 1 tonne/acre from fields adjacent to water courses, water quality may be affected.

TABLE 1: Potential soil erosion (tonnes/acre/year).

Soil type	Crop	Slopes (%) 0-0.5	0.5-2	2-5	5-9	9-15
Loam	Corn	3	3	9	24	47
	Grain	3	3	8	23	44
	Forage	<1	<1	2	5	10
	Woodlot	<1	<1	1.5	4	8
Silt loam, Silty clay loam	Corn	4	4	12	31	59
	Grain	4	4	11	29	55
	Forage	<1	<1	2.5	6	12
	Woodlot	<1	<1	2	5	10
Sandy loam	Corn	1.8	1.8	5	13	25
	Grain	1.6	1.6	4.5	12	23
	Forage	<1	<1	1	2.7	5
	Woodlot	<1	<1	<1	2	4

The use of conservation tillage techniques including cross slope cultivation and planting, residue management using conservation tillage equipment, crop rotation with forage grasses and legumes, cover crops, and buffers may reduce the erosion potential to an acceptable level for agronomic and water quality reasons.

Erosion of soils, transportation, sedimentation and resuspension has resulted in an average sedimentation rate in the east end of Cootes Paradise of 1 cm/year. Suspended solids concentrations as high as 2,300 mg/l were observed in a 1987 runoff event in Spencer Creek. Urban construction practices in Dundas are felt to be the major contributor, since the watershed above the escarpment has a flood control reservoir which would dampen the impact of rainfall events (Ecologistics, 1988). Grindstone Creek also has significant erosion events that have resulted in the deposition of clay/silt sediments at its mouth in Hamilton Harbour. As far back as 1966, erosion was identified as a serious problem in Grindstone Creek. In 1966-67, Grindstone Creek discharged 2,260 tons of suspended solids. When compared to other area creeks and rivers, Grindstone was by far the worst. Grindstone, Spencer and Red Hill Creeks had 87, 42 and 10 tons respectively per year per cfs of suspended solids in 1969. The following types of erosion were observed in the Grindstone Creek watershed: sheet, rill, gully, channel, in-stream, unstabilized stream banks, urban construction practices, road embankments, and excavations. A 1978 survey concluded that the majority of the suspended solids originated in the lower portion of Grindstone Creek, below the escarpment. Steep slopes combined with relatively impervious clay and shale deposits resulted in the rapid erosion of any exposed soil.

The average annual sedimentation rate in the Harbour has been estimated from limited sediment trap data to be approximately 6.5 $g/m^2/day$ (M. Charlton,

NWRI, unpub. data). The total annual amount settling out over the entire Harbour would be approximately 5.2 x 10^7 kg. Assuming an average surficial sediment weight of 0.34 g/cc (Nriagu et al., 1983), the sedimentation rate measured in the water column translates to an annual deposition of 0.7 cm/yr. Nriagu et al. (1983) determined a deposition rate of between 0.12 cm/yr and 0.35 cm/yr. Examination of their sediment profiles of trace metals would suggest that the 0.35 cm/yr rate is a good estimate of the deposition rate over the past 30-40 years. A net accumulation rate of 0.3 cm/yr was also determined for the area in Lake Ontario, outside the Burlington Ship Canal (Poulton et al., 1988).

The suspended sediment loading from streams has had a significant negative impact on aquatic habitat at the mouths of the streams. The general sedimentation rate across the complete Harbour will figure significantly in the discussion of contaminants in the bottom sediments.

II.2 Current Land Uses

II.2.1 Introduction

A land use survey has not been conducted on the complete Hamilton Harbour watershed. Some general features can, however, be presented (Figure 3).

Urban centers located in the watershed are Hamilton (pop. 360,000), Burlington (120,000), Stoney Creek (25,000), Dundas (20,000), and Ancaster (15,000). Projected population increases for the basin are approximately 10% from these 1982 estimates to the turn of the century. Urban growth within the watershed has historically centered on the City of Hamilton. Development has resulted in a nearly continuous urban area surrounding the Harbour. The urban centers are largely below the Niagara Escarpment. The greatest pressure for development is in the eastern and north-eastern parts of the watershed.

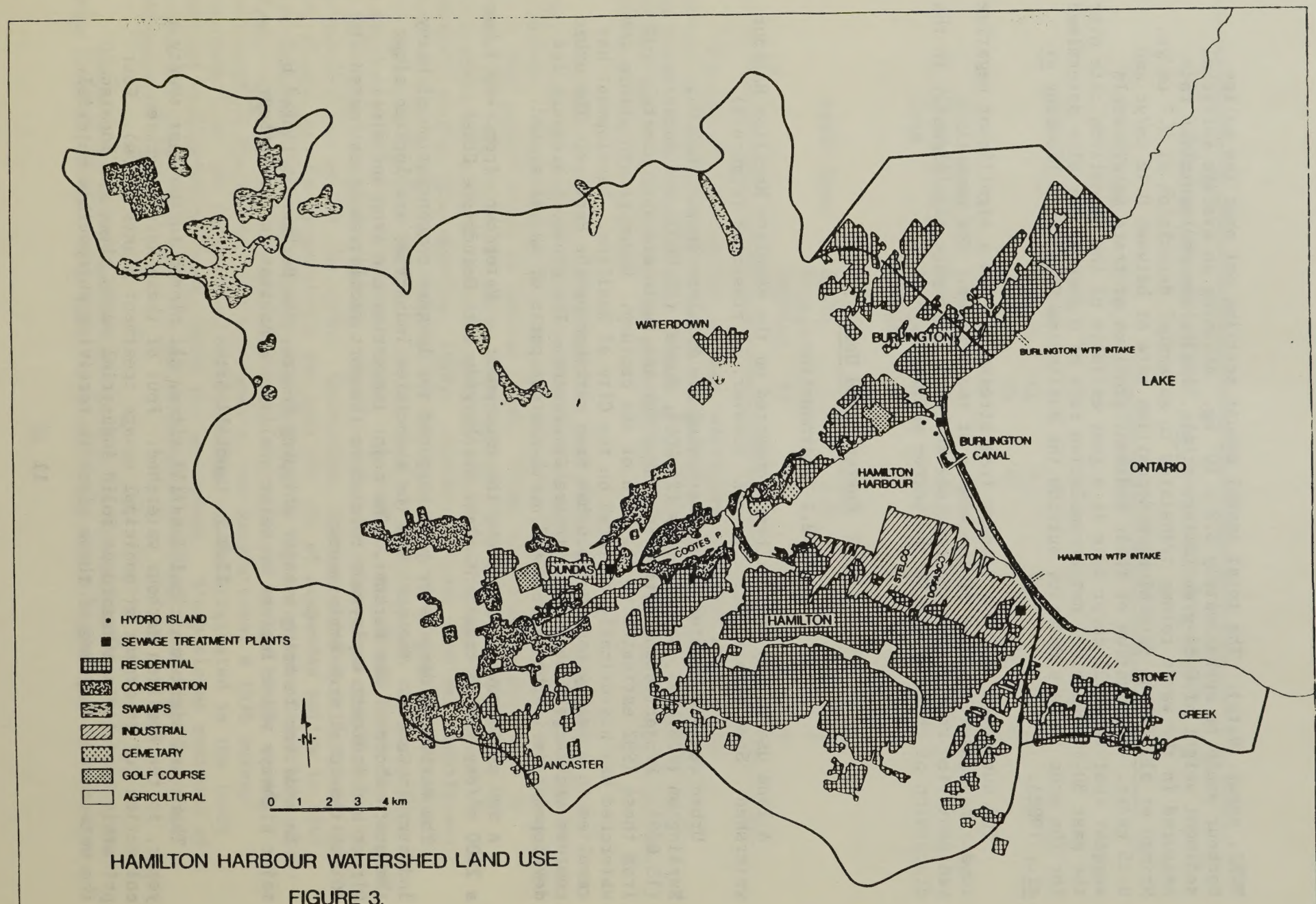
A few small towns exist above the escarpment. Waterdown (pop. 4000) has a 2400 m^3/day sewage treatment plant discharging into Grindstone Creek.

The Harbour's deep water port supports the largest concentration of heavy industry in Canada. The port and the associated industries are located along the south shore of the Harbour. The major industries are iron and steel. Direct and indirect employment related to the port facilities is estimated at 30% of the total area employment.

In addition to being a major shipping centre, the Harbour is ringed by major highways which impinge on water quality and habitat in the Harbour.

II.2.2 Landfill Sites

There are eight municipal landfill sites, all closed in the last twenty years, in the Hamilton Harbour watershed. Four of these have leachate collection for treatment at municipal sewage treatment plants (STPs). Four privately operated non-hazardous solid industrial waste sites are located in the watershed. Only one of these sites is receiving putrescible material.



HAMILTON HARBOUR WATERSHED LAND USE

FIGURE 3.

Leachate from this site is being collected for treatment at a municipal STP.

Studies have been carried out at all landfill sites and reports are available from the regional MOE office. No detrimental effect on receiving waters is being observed at any of these sites.

The Burlington Landfill site is approximately 29.3 hectares and was closed in 1989. The site is adjacent to Falcon Creek, approximately 3.5 kilometers from Hamilton Harbour. The leachate is collected for treatment at the municipal STP. The Halton Region also has a detailed monitoring program for Falcon Creek.

The Bayview Park Landfill site in Burlington closed in 1972 and occupied an area of approximately 18 hectares. The site is adjacent to Indian Creek. A leachate collection system was installed in 1986 for pumping and treatment of the leachate at the Burlington STP. The Halton Region has a detailed monitoring program for ground and surface water quality.

The 403 Landfill site was closed in 1977 and is now Kay Drage Park. The 15 hectare site is adjacent to Chedoke Creek in Hamilton. No leachate collection system is in place. Sampling of Chedoke Creek is done above and below the park.

The Edgewood Road Landfill site in Flamborough was closed in 1978. The 4 hectare site is adjacent to Beverly Swamp.

The Dundas Landfill site in the town of Dundas was closed in 1976. The 9.4 hectare site has been sampled by the Region of Hamilton-Wentworth.

The Brampton Street Site is approximately 5 hectares and was closed in 1977. The site is adjacent to Red Hill Creek in Hamilton. Red Hill Creek is monitored by the regional office of the Ministry of Environment.

The Upper Ottawa Street Landfill site in Hamilton was closed in 1980. The site is 1 kilometer north of the escarpment adjacent to Red Hill Creek. Leachate collection systems have been installed and the leachate is pumped to the Woodward Avenue STP. An Upper Ottawa Street Landfill Site Study was produced in 1986. Monitoring is performed by the Ministry of Environment and the Region of Hamilton-Wentworth.

The Jersey Road Landfill site in Ancaster was closed in 1980. The 19.8 hectare site has a leachate collection system and the leachate is pumped to the Woodward STP.

The Steetley Industries Landfill site is approximately 16.3 hectares and is located in the Town of Flamborough. The site is limited to non-hazardous solid industrial waste. Leachate is collected and pumped to the Dundas STP. A groundwater monitoring program is also performed.

Taro Aggregates Landfill site in Stoney Creek is approximately 24.3 hectares and is also limited to non-hazardous solid industrial waste. A groundwater monitoring program is conducted.

Stelco Inc. Landfill Sites (No. 2 Rod Mill and No. 3 Dock) are approximately 18.5 hectares and 35.4 hectares respectively. They are constructed on landfill in the Harbour and are restricted to non-putrescible non-hazardous industrial waste. Groundwater monitoring programs are performed by Stelco and annual reports sent to the Ministry of Environment.

II.2.3 Agricultural

Approximately 60,000 hectares in the Hamilton Harbour watershed is classified as agricultural. About 15% of this land is woodland, and the remainder is intensively cropped. Of the farms in the area, the Agricultural Census (Statistics Canada, 1986) reports that about 80% are mixed farms, raising livestock and growing hay, cereal grains and corn; 10% are tree fruit farms; and 10% are vegetable farms. A few nurseries and sod farms also operate in the watershed.

Farmers apply nitrogen, phosphate and potash fertilizers and lime to field and horticulture crops according to recommendations based on the soil test requirements. The summary of the 1986 Ontario Ministry of Agriculture and Food soil testing information indicates that farmers in the regions of Hamilton-Wentworth and Halton tested 1,487 soil samples. The average soil test values for all crops indicate the soils are neutral in pH with an average phosphorus reading of 32 and an average potassium reading of 124. These average values are slightly higher than the provincial average due to the horticultural crops grown.

Herbicide and pesticide use in the two regions is summarized in Table 2.

The agricultural use of land in the Hamilton Harbour watershed, especially adjacent to watercourses, may have some effect on water quality in the rural areas if recommended management techniques are not followed. Where recommended crop and livestock management practices are followed, the impact of agricultural use of land on water quality is expected to be minimal.

TABLE 2: Herbicide and pesticide use in 1983 (kg).

		Herbicides			Insecti-	Fungi-
	Crop	Triazine	Phenoxy	Other	cides	cides
Hamilton-Wentworth Region	Field	25350	8070	26460	6670	0
	Fruit	130	10	270	7930	23520
	Veg.	730	310	2420	4850	4980
	Roads		880	110		
Halton Region	Field	7370	2350	0	0	0
	Fruit	10	0	70	2420	6420
	Veg.	100	10	280	600	760
	Roads		670	20		

Source: Ontario Ministry of Agriculture and Food, 1983.

II.2.4 Recreational

The Hamilton-Wentworth Conservation Authority has 13 conservation areas in the watershed for a total of approximately 2,000 hectares. Most of these areas support recreational activities such as hiking, bird watching, family picnics, fishing, swimming, canoeing, and sailboarding. Cootes Paradise is a 835 hectare nature preserve owned and managed by the Royal Botanical Gardens (RBG). Numerous passive recreational activities are supported by Cootes Paradise. Public use of Cootes Paradise and the RBG natural areas for outdoor education and enjoyment is approximately 63,000 user days per year. The Niagara Escarpment with its associated natural areas and trails is also a major recreational resource.

II.2.5 Wildlife Habitat

The Cootes Paradise/Hamilton Harbour area lies within two broad and overlapping life zones: the Great Lakes-St. Lawrence, and the Carolinian (Deciduous Forest Region). The Carolinian life zone is widespread in the eastern United States but only extends into Canada in southwest Ontario in the area bordered by Lakes Huron, Erie and Ontario. Consequently the flora and fauna reflect elements of both of these major biomes. Nationally, provincially, and regionally significant plant and animal species are present. Sixteen rare mammals, 25 rare fish, 53 rare breeding birds, and 22 rare reptiles and amphibians have been identified in the Hamilton-Wentworth Region.

The Niagara Escarpment, Dundas Valley, Red Hill Creek Valley and upland areas of Cootes Paradise and Grindstone Creek Valley comprise a continuous green belt providing corridors for wildlife utilization within the region.

II.2.6 Environmentally Sensitive Areas

Environmentally sensitive areas (ESAs) are areas with some inherent biological sensitivity, and were identified using the criteria established by conservation authorities and the Halton Region Ecological and Environmental Advisory Committee. ESAs are areas containing or representing:

1) unusual and/or distinctive landforms
2) vital ecological functions (water storage, headwaters, habitat)
3) unusual/distinctive plant and/or animal communities
4) unusual/distinctive habitat
5) high diversity of biological communities
6) habitat for rare or endangered species
7) large and undisturbed area
8) other combination of habitat/landforms valuable for research or education
9) other combination of habitat/landforms with a high aesthetic value

The Hamilton-Wentworth Region has a total of 44 ESAs of which 27 are in the Hamilton Harbour watershed (11,400 ha.). The Halton Conservation Authority has a total of 38 ESAs with 5 contained in the watershed (600 ha.). Twenty-five percent of the Hamilton Harbour watershed has been identified as environmentally sensitive areas.

The ESA policy is designed to protect significant natural areas within the limits provided by existing legislation. The intent of the policy is not to unnecessarily restrict development within the ESA, but rather to ensure that such development does not adversely affect the ESA as determined through preparation of environmental impact assessments. In many cases, ESAs may need all or large portions of their area to be protected.

Many of the areas are also identified by other agencies as special areas such as the Parkway Belt West Plan, the Niagara Escarpment Commission Mandate, Class 1 Wetlands, Carolinian Canada, or ANSI (Areas of Natural Scientific Interest).

II.3 Current Water Uses

II.3.1 Water Supply

The drinking water supply for Hamilton area and Burlington residents is Lake Ontario. Water is drawn from intakes 5 kilometers south and north from the Ship Canal. Ultimately, 368,000 m^3/day of what originally was Lake Ontario water is processed at the Hamilton and Burlington sewage treatment plants for discharge into Hamilton Harbour.

II.3.2 Navigation

Hamilton Harbour is the second largest Canadian Port on the Great Lakes and ranks sixth for total tonnage in Canada. Imports include general cargo, steel, ingot moulds, machinery and fertilizers. Exports include steel, general cargo, beans, grain, newsprint, rubber, synthetic resin, road graders, ductile iron water pipe, and cement. Bulk shipments of coal, iron ore, sand, scrap metal, petroleum products, and molasses are handled.

Since 1922, the tonnage handled in the port has steadily increased. In the past ten years, however, the level of shipping activity in the Harbour has fluctuated. Tonnage has levelled off (11 million metric tonnes) and is expected to remain relatively stable with modest yearly increases.

On behalf of the Hamilton Harbour Commission (HHC), Public Works Canada oversees regular maintenance dredging projects which maintain the required navigational depth (approx. 9 m) in the main ship channels and slips. From 1976 to 1984, 350,000 m^3 of sediments have been dredged from the Harbour and placed in the confined disposal facility (CDF) managed by the Hamilton Harbour Commission at the east end of the Harbour.

II.3.3 Wildlife

Hamilton Harbour has six areas within the basin identified as having significant wildlife associations. The areas are: Cootes Paradise, Hendrie Valley/Carrolls Point, the Hamilton Harbour Commission's Confined Disposal Facility, Hydro Islands, Windermere Basin, and Hamilton Harbour proper.

The west end of Lake Ontario, including Hamilton Harbour, is an important

local and regional waterfowl habitat area (Dennis et al., 1984). The North American Waterfowl Management Plan has specific objectives regarding the acquisition and protection of 27,300 hectares of breeding and migration habitat for black ducks and mallards within the Canadian St. Lawrence-Great Lakes Lowlands area.

The Ontario Ministry of Natural Resources has classified Cootes Paradise as a Class One Wetland, the highest ranking classification. Given the importance of the area for waterfowl both locally and within the context of the North American Waterfowl Management Plan, and given the serious reduction in the critical marsh littoral habitat, Cootes Paradise could achieve regional and national prominence if its wetlands and waterfowl usage could be improved.

II.3.4 Recreation

The calm waters of the Harbour are enjoyed by many sailing and rowing enthusiasts. Many individuals fish for salmon, trout, bass, pike, and panfish. Swimming is prohibited by a bylaw of the Hamilton Harbour Commission.

At present, 737 boat slips, 250 moorings and 70 dry sail spaces are available in the Harbour. Approximately 70% are occupied by sailboats and 30% by power boats. Four ramps are provided, two in Hamilton and two in Burlington. Seven boat clubs or marinas are located in the Harbour, with all except one located in the southwest corner. These recreational boating facilities provide approximately 78,000 user days per year. Increased canoeing and kayaking activities have been noted in Cootes Paradise and the Harbour, but the extent has not been measured adequately.

The Ontario Angler Survey and annual creel surveys indicate that fishing activity is predominately in Lake Ontario and oriented toward cold water species. Almost all of the fishing in the Harbour has been observed to be shore fishing. Several warm water and cold water species are caught in the Harbour. The total user days are an estimated 4400 per year.

II.3.5 Waste Disposal

The Hamilton and Burlington sewage treatment plants (STPs) discharge into Hamilton Harbour (391,000 m^3/day). All industries in Hamilton discharge their wastes to the sewage treatment plant; however, both Stelco and Dofasco discharge a portion of their waste directly to the Harbour after on-site treatment. Combined sewers do overflow during heavy rains and result in sewage entering the Harbour directly.

II.3.6 Industrial Uses

Both of the iron and steel industries withdraw water for direct contact cooling (2×10^6 m^3/day) but virtually all is returned to the Harbour. This "once-through" cooling process presents the industries with serious difficulties in controlling contaminant discharges. Discussion concerning effluent discharges (concentrations and loadings) appears in Chapter IV.

II.4 Political Jurisdictions

Hamilton Harbour and its watershed encompasses a number of municipal jurisdictions (Figure 4). In addition, there are many agencies with legislated mandates that have an impact on the Harbour. One of the major challenges in trying to realize fully the beneficial uses affected by water quality will be to coordinate the work of these agencies to achieve common goals. It is therefore necessary to identify where these mandates reside.

Historically, the Constitution Act of 1867 (British North America Act) gave the issue of free navigation primacy over all other uses within public harbour areas. Public harbours were the property of the federal government. Harbour jurisdiction extended to the bed and the foreshores of the harbour, where these foreshores were actually used for harbour purposes. Autonomous Harbour Commissions were created to manage and administer public Harbours on behalf of the federal government.

II.4.1 Hamilton Harbour Commission

Hamilton Harbour was not a public harbour at the time of Confederation in 1867. The City of Hamilton was given jurisdiction over the Harbour area when the city was incorporated in 1846. The Hamilton Harbour Commission Act of 1912, gave the authority to the Hamilton Harbour Commission (HHC) to administer the Harbour on behalf of the City of Hamilton. This authority applied to all waters and inlets of the Harbour, and all waterfront properties, water lots, docks, shores, and beaches. The act gave the HHC jurisdiction over lands developed for shipping and Harbour uses and the power to regulate the use of Harbour foreshore lands. The HHC passed its own by-laws to control activities relating to shipping and navigation within the Harbour or on Harbour land.

As indicated in Section II.4.5, a court decision in 1978 ruled that the City can regulate land use within the Harbour area, as long as that land use does not interfere with shipping or navigation uses. Where conflicts arise, federal jurisdiction over shipping and navigation prevails.

The federal government appoints two commissioners to the Hamilton Harbour Commission. The third commissioner is appointed by the City of Hamilton. The HHC submits an annual report on activities and a financial statement to the Minister of Transport. However, it conducts its activities independent of the Minister of Transport.

II.4.2 Federal

The authorities for federal jurisdiction in Hamilton Harbour derive primarily from the Canada Shipping Act, the Navigable Waters Protection Act, the Public Works Act as it pertains to navigational dredging, and the Fisheries Act. The federal government owns some water lots adjacent to the Canada Centre for Inland Waters (CCIW).

Apart from the Burlington Ship Canal, which is the responsibility of Transport Canada, the federal government has in the past exerted very little direct jurisdiction over Hamilton Harbour.

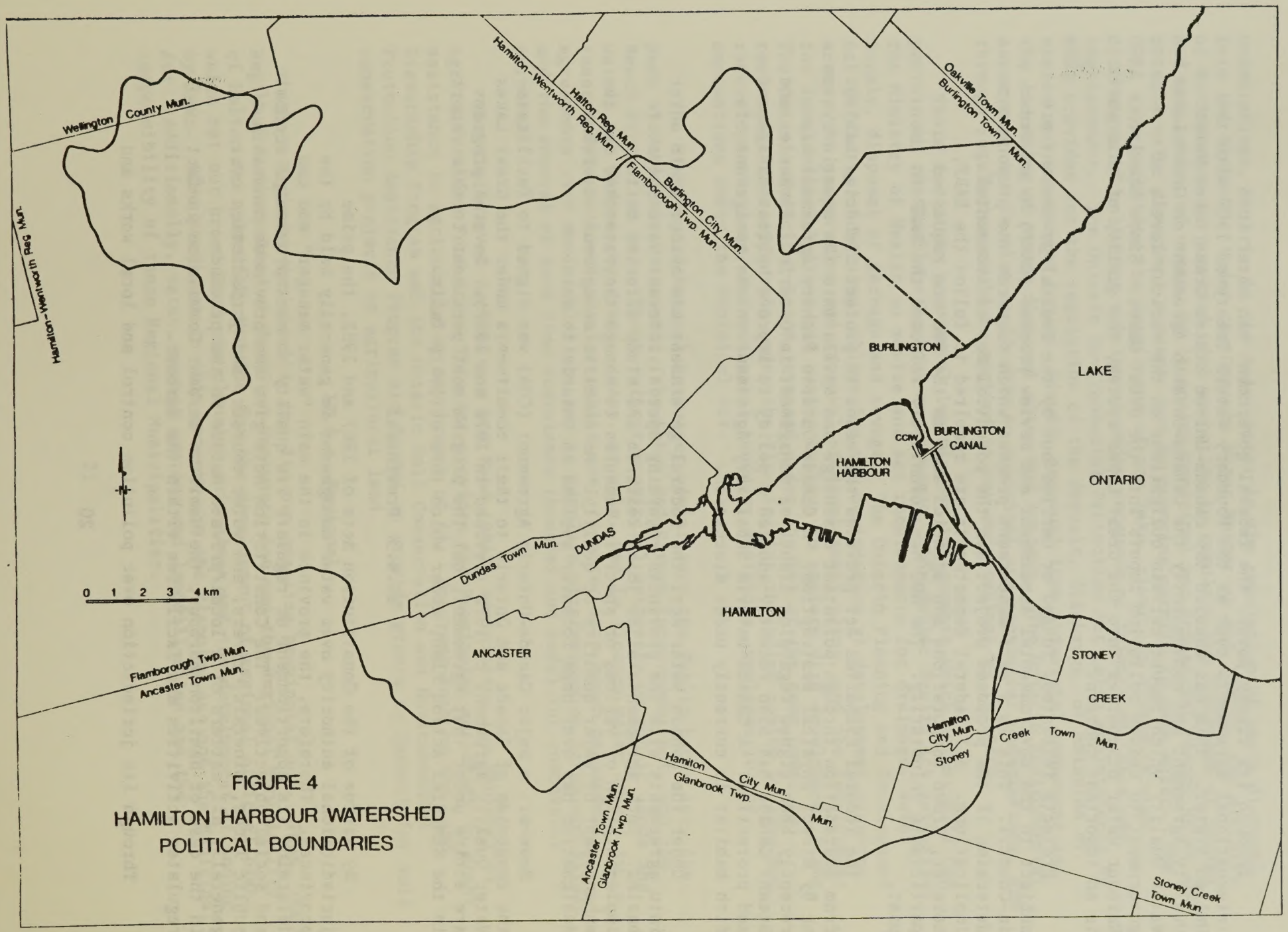


FIGURE 4
HAMILTON HARBOUR WATERSHED
POLITICAL BOUNDARIES

Through its treaty power, the federal government can enter into international agreements such as the Boundary Waters Treaty of 1909 with the United States. This has enabled the Canada-United States Great Lakes Water Quality Agreement and consequently the Canada-Ontario Agreement on Great Lakes Water Quality which impose certain obligations on the various levels of government to reduce pollution inputs into the Great Lakes. Since Hamilton Harbour water discharges into the Great Lakes system, the quality of this water is an important concern.

Projects initiated, funded or carried out by the federal government are subject to the Environmental Assessment and Review Process (EARP) by an Order-in-Council. This is a self-assessment process which requires the proponent to determine if the proposed project has the potential for environmental implications. All federal departments are required to follow the EARP, however, Crown Corporations and agencies such as the HHC are requested to participate voluntarily. The HHC has voluntarily followed the EARP in the past.

The federal Fisheries Act provides the means to protect fisheries habitat from degradation through pollutant discharge and spills into the aquatic system or by direct physical destruction. A Canada-Ontario Fishery Agreement has recently been signed regarding fisheries management in Ontario. Fisheries and Oceans Canada has also recently adopted a policy to improve habitat management and protection. A Canada-Ontario Subsidiary Agreement on the management of fish habitat is currently under discussion.

Under the Canada Water Act, the federal government has authority to enter into agreements with the provinces regarding special interest watersheds or basins. Such agreements allow joint research and study efforts, or the implementation of various or specific measures to manage the watershed for the enhancement of water quantity or quality. No specific management watershed designation has ever been formally applied in Ontario to date.

However, a major Canada-Ontario Agreement (COA) was signed to facilitate the responses of Canada and Ontario to their commitments under the Great Lakes Water Quality Agreement of 1972 (revised in 1978 and 1987). Several programs are active under that Agreement, but the program most pertinent to this report is the Remedial Action Plan, under which this activity falls.

II.4.3 Provincial

By virtue of the Constitution Acts of 1867 and 1982, the prime jurisdictional authority over water management is generally held by the provinces. Therefore, the province is the main "water manager" and can determine its apportionment or regulate its quality to meet provincial economic and social objectives. The Constitution Acts give the provinces ownership of public lands, minerals, rivers, and water courses, and jurisdiction over generally all matters of a local/private nature in the province.
In the case of Hamilton Harbour, the Hamilton Harbour Commission in fact regulates activities and facilities within the Harbour.

Through its jurisdiction over pollution control and local works and

undertakings, Ontario is the major actor in the regulation of waste disposal into the Harbour. Under the Ontario Water Resources Act (OWRA), the Ministry of Environment is provided with authority to regulate the discharge of sewage and the taking of water, by licensing municipal and industrial sewage works and potable water treatment systems, and by granting permits to take water. The OWRA also prohibits the impairment of any lake, river, or stream through discharges of polluting substances under recourse of injunction, fine and imprisonment. The Ontario Environmental Protection Act (also administered by MOE) provides for the regulation of the deposit, discharge, or emission of wastes and substances (solid, liquid, gaseous) from industrial processes and the licensing of waste disposal sites and systems. The Ontario Environmental Assessment Act is also applicable to municipal and provincial undertakings, and through regulation could be applied to new undertakings by industry.

There are other provincial legislative instruments which potentially can pertain to the Hamilton Harbour environment. The Public Health Act authorizes the Ministry of Health to advise and set requirements for drainage, water supply, disposal of garbage and sewage. The Ontario Planning and Development Act (Ministry of Housing) allows for the designation of development planning areas, the preparation and approval of development plans, and the requirement for local official plans and zoning by-laws to conform with development plans. The Ontario Municipal Board, created under the Act of the same name, is responsible for approvals under the Planning Act including zoning by-laws and redevelopment plans, and municipal boundary revisions, amalgamation or annexations under the Municipal Act.

The Ministry of Natural Resources administers the Public Lands Act, the Beds of Navigable Waters Act, the Lakes and Rivers Improvement Act, and the Beach Protection Act. These reflect provincial authority on public lands and waters (to dispose by grant, lease, or sale, and to licence water lots); to reserve 25% of shorelands for public use; to enter into beach management agreements with municipalities; and to regulate alterations on lakes and rivers and the removal of sand from shorelands (beaches and beds) for commercial purposes.

The Ministry of Agriculture and Food (OMAF) administers the Ministry of Agriculture and Food Act. This Act provides the Provincial authority to grant assistance to agriculture or any branch of it. Programs such as the Land Stewardship Program and the Ontario Soil Conservation and Environmental Protection Assistance Program are funded to provide grants to farmers for soil conservation projects on agricultural land.

II.4.4 Regional

Each Regional Municipality has its own enabling provincial act. Thus, the Regional Municipality of Hamilton-Wentworth Act and the Regional Municipality of Halton Act generally provide for the development of regional official plans which set out broad land use planning guidelines and the development of zoning by-laws. Also pertinent in this context are the Planning Act and the Municipal Act. Additionally, water, sewage systems and landfill sites are the responsibility of these Regional Municipalities.

II.4.5 Municipal

Both the City of Hamilton and City of Burlington which front onto Hamilton Harbour (Figure 4) operate within the context of the Municipal and Planning Acts, and within the framework of their respective Regional Municipalities. The municipal governments develop district plans which are implemented by specific re-zoning or by-law amendments, subdivision approvals, agreements, and site plan controls, such as through the issuing of building permits. Under the Planning Act, the City can prohibit or otherwise regulate the use of all lands and improvements within the municipality, subject to Ontario Municipal Board approval. The City of Hamilton has, for example, enacted a by-law (#6593) which restricts certain uses and characteristics of land and building structures within its boundaries, which include the adjoining shores of Hamilton Harbour, Cootes Paradise, and Lake Ontario. Based on a court decision in 1978, however, city by-laws affecting land use within the Harbour are only applicable where they do not explicitly attempt to control the use of land for shipping or navigation related purposes.

II.4.6 Conservation Authorities

The Conservation Authorities Act, administered by the Ministry of Natural Resources, establishes provincial regional Conservation Authorities (with representation of local municipalities) to conserve, develop and manage all natural resources, with the exception of oil, gas and minerals, within their designated watersheds. The Act provides authority to construct dams and create reservoirs, control the flow of surface waters, alter watercourses, and make regulations regarding the use of water in rivers and lakes (subject to approval of the Lt. Governor-in-Council). It also allows the Conservation Authority to regulate changes in watercourses, construction in flood-prone areas, and the dumping of fill into water.

Since the Hamilton Harbour Commission Act of 1912, jurisdiction over Cootes Paradise has been transferred to the Royal Botanical Gardens. The jurisdiction of the Hamilton-Wentworth Region Conservation Authority has been found by courts not to extend into Hamilton Harbour for purposes of regulating or prohibiting the dumping of fill. Infilling is a major issue relating partly to water quality, but more significantly to alterations in habitat within the Harbour and Cootes Paradise.

II.5 Water, Sediment, and Biota Guidelines and Objectives

II.5.1 Introduction

The principal tools used by regulatory agencies in enforcement for environmental or human health concerns are water quality objectives, water and sediment quality standards, or water quality guidelines. These are numerical "targets" set on a substance-by-substance basis, and set with regard to the best information available at the time of their establishment. These standards change from time to time, as new information comes forward. They usually have built into them safety factors of 100 to 1000, especially for contaminants that could potentially affect human health.

Whether for human health concerns or for concerns about living organisms in the natural environment, it is possible that these standards are necessary, but not sufficient, conditions. In each individual site situation it is therefore necessary to assess the biological system that we are attempting to protect - to assure that the system is receiving the benefit of our remedial action.

While we use these standards as initial guideposts, they should be assessed in relation to the biological communities. This should be reflected in the monitoring program design and in assessing structural and functional changes in the biological systems of the Harbour (Stokes and Piekarz, 1987).

II.5.2 Provincial Water Quality Objectives

The Provincial Water Quality Objectives pertinent to the present and future uses of Hamilton Harbour are a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water (MOE, 1978). They define a desirable level of water quality that the Ministry strives to maintain in surface waters of the Province. The Objectives for raw water supplies for drinking water are generally not as restrictive as the Objectives for the protection of aquatic life.

The Objectives for recreational water uses are based on public health and aesthetic considerations. The Objectives for aquatic life are set at such values as to protect all forms of aquatic life and all aspects of the aquatic life cycles. The clear intention is to protect all life stages during indefinite exposure to the water. When insufficient information exists to develop an Objective, a Guideline is provided with the understanding that site-specific information would be necessary to manage the water body with respect to the chemical in question. Phosphorus is an example were the Province has supplied only a Guideline.

Table 3 lists the Provincial Water Quality Objectives for those chemicals which currently or in the past have caused concern in Hamilton Harbour. If a chemical is not listed in Table 3, its Objective has routinely been met in the Harbour.

II.5.3 Canadian Water Quality Guidelines

The Task Force of Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers published Canadian Water Quality Guidelines (CCREM, 1987). The federal Guidelines listed in Table 3 are specific for the protection of freshwater aquatic life. Guidelines for some of the chemicals vary with water hardness, temperature or pH. The values reported in Table 3 are adjusted for the hardness and pH conditions within Hamilton Harbour.

II.5.4 IJC Water Quality Objectives

The International Joint Commission also has Water Quality Objectives (IJC, 1978) (Table 3). The Objective for phosphorus is to minimize eutrophication problems and to prevent degradation with regard to phosphorus in the boundary waters of the Great Lakes System. The goals of phosphorus control are

Table 3: Water Quality Objectives pertinent to Hamilton Harbour. All units in µg/l unless specified otherwise.

Parameter	Objectives		
	Provincial	Federal	IJC
Aluminum	-	0.1 mg/l	-
Ammonia (Nitrogen)	20[1]	0.4-2 mg/l[2]	20[1]
Arsenic	100	50	50
Cadmium	0.2	1.3	0.2
Chlorine	2	2	-
Chromium	100	20 (fish) 2 (plankton)	50
Copper	5	3	-
Cyanide	5	5	-
Diss. Oxygen	4-5 mg/l	5-6 mg/l	6 mg/l
Iron	300	300	300
Lead	25	4	25
Mercury	0.2	0.1	0.2
Nickel	25	110	25
Phosphorus	20[3]	20[3]	20[3]
Zinc	30	30	30
Phenol	1	2	-
DDT	3 ng/l	1 ng/l	3 ng/l
PCBs	-	1 ng/l	0.1 µg/g fish
Mirex	-	-	<DL[4]
Total Diss. Solids	-	500 mg/l[5]	200 mg/l
Turbidity	10% Secchi increase	10 mg/l susp. solids increase	10% Secchi increase
Clarity	1.2 m Secchi	1.2 m Secchi	-
Fecal Coliforms	100/100 ml	-	-
Total Coliforms	1000/100 ml	-	-

Petrochemicals: Oil and grease should not be present in concentrations that a) can be detected as a visible film, sheen, or discolouration on the surface; b) can be detected by odour; c) can cause tainting of edible aquatic organisms; or d) can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms.

Temperature: Water discharge should not alter the natural thermal regime of the receiving water body.

PAHs: There is insufficient information to establish specific guidelines.

1. Un-ionized ammonia
2. Total ammonia
3. General guideline; specific objectives are set for each site.
4. Below detection limit
5. Drinking water Objective

specified in Annex 3 of the Great Lakes Water Quality Agreement of 1978. The goal most appropriate to Hamilton Harbour is the elimination of algal nuisance wherever they occur. Hamilton Harbour is defined as a part of the Boundary waters designated in the Agreement.

II.5.5 Water Quality, Habitat and Use Objectives for Cootes Paradise

In response to requests from the Ontario Ministry of the Environment, the Royal Botanical Gardens established water quality (Table 4), habitat and use Objectives for Cootes Paradise in 1975. The intent of the Objectives was to ensure that plant and animal life were not depressed or killed by chemical substances or suspended solids from upstream areas. The objectives were intended to be realistic levels of chemical and physical parameters that will ensure the survival of fish, bottom fauna, insects and plant life in all parts of Cootes Paradise.

Table 4: Water Quality Objectives for Cootes Paradise

Parameter	Maximum
Chlorophyll (May-October)	50 µg/l
Ammonia (un-ionized)	20 µg/l
Turbidity (Jackson Units)	25 JU
BOD (effluent quality)	<5 mg/l
Dissolved Oxygen	>4 mg/l
Chlorine	<0.11 mg/l

Habitat Goals

The open water area of Cootes Paradise is currently 250 hectares (1975). It is anticipated that approximately 50% or 190 hectares will be suitable for macrophyte restoration and manipulation with the goal of producing a high quality habitat complex for waterfowl and other marsh-dependent wildlife.

Objectives

1. Foremost, to maintain this water and marsh habitat with contiguous lands as a wildlife sanctuary by protecting the integrity of habitats for a rich variety of flora and fauna through a firm stand on all activities which interfere with diverse ecological interactions and militate against such a preservation policy.

2. To provide limited public access and interpretative facilities for public education and quiet appreciation only to an extent consistent with #1.

3. To continue to provide reasonably natural aquatic and terrestrial habitats for studies in environmental science by students at all levels.

Use Goals

The objective is to ensure that Cootes Paradise becomes a suitable aquatic habitat for the following natural biological components, for aquatic biological studies and for specific limited aspects of public recreation.

The aquatic habitat of Cootes Paradise must be made suitable for the needs of a full range of resident organisms common to similar habitats in southern Ontario. These include birds, animals, amphibians, invertebrates and plants. Advanced pollution reduces diversity: the goal here is to achieve diversity in these components through water quality improvement.

Cootes Paradise, with other major natural aquatic areas, plays an important role in successful bird migration, (particularly waterfowl) in both spring and autumn. Water quality influences the production of food and cover for migrating waterfowl.

Both native and introduced lake fish enter Cootes Paradise and its tributaries to spawn. Water quality must be conducive to their survival and the survival of fry which hatch and journey back to Lake Ontario. Water quality must be such that Cootes Paradise can play its part in the regeneration of fish to serve the resurgence of fishing in Lake Ontario.

Present high coliform counts in the inflows of Chedoke Creek and upper Desjardin Canal prevent any use of these areas for aquatic studies beyond those of researchers trained to work in polluted waters. Water quality must be such that school classes and the public on interpretive excursions will not contract skin diseases or infections from handling specimens or dipping into the water. Many unique research opportunities exist with McMaster University which is within walking distance of Cootes Paradise.

While it is not suggested that the waters of Cootes Paradise meet the standards of total immersion sports, coliform counts must be drastically lowered before encouraging quiet boating without health hazard.

II.5.6 Provincial Open-Water Disposal Guidelines

The Ministry of Environment has Guidelines for the open-water disposal of sediment dredged for navigation purposes (MOE, 1987c) (Table 5). If contaminants in the sediments exceed the Guidelines then the sediment must be either disposed of on land or in a confined disposal facility (CDF). These are cells to hold sediment, and are surrounded by berms and capped with clean material. The Hamilton Harbour Commission manages such a facility on the east shore of the Harbour, south of the shipping canal. It is used for sediments dredged for navigational purposes. The Ministry of Environment is drafting new Open Water Disposal Guidelines which will include numerical criteria for contaminants, based on biological effects. These new guidelines are not official yet but are being applied in practice. The United States Environmental Protection Agency also has guidelines for the classification of contaminated sediments. The EPA "heavily polluted" criteria are included in Table 5 for comparison.

TABLE 5: Existing Guidelines for disposal of dredged sediment. All units in µg/g unless otherwise specified.

	MOE Open-Water	EPA Heavily Polluted
Organic Content	6%	>8%
Sediment Oxygen Demand	50 mg/g	>80 mg/g
Ammonia (NH_3)	100	>200
Total Kjeldahl Nitrogen	2 mg/g	>2 mg/g
Total Phosphorus	1 mg/g	>0.65 mg/g
Iron	10 mg/g	>25 mg/g
Copper	25	>50
Chromium	25	>75
Nickel	25	>50
Zinc	100	>200
Lead	50	>60
Cadmium	1	>6
Mercury	0.3	>1
Cobalt	50	-
Arsenic	8	>8
Ether Ext.	1.5 mg/g	>2 mg/g
PCBs	0.05	>10

II.5.7 Fish Consumption Guidelines

The Ontario Ministries of the Environment, Natural Resources and Labour cooperate in a monitoring program called the Sport Fish Testing Program. Annually the "Guide to Eating Ontario Sport Fish" is published providing advice on recommended levels of consumption of game or sport fish from over 1400 of Ontario's lakes, rivers, and locations on the Great Lakes (MOE, 1988a). The substances included in the monitoring program are mercury, copper, nickel, zinc, cadmium, manganese, chromium, arsenic, selenium, lead, PCBs, DDT, Mirex, Dioxin, HCB (hexachlorobenzene), Lindane, Heptachlor, Aldrin, Chlordane, and Toxaphene.

The consumption guidelines are based on the Canadian Government Health Protection Guidelines. The guidelines reflect the maximum recommended consumption of fish according to the contaminant content and the duration of the consumption (one, two, three weeks and long-term).

III DESCRIPTION OF ENVIRONMENTAL CONDITIONS IN HAMILTON HARBOUR

III.1 Physical Processes

III.1.1 Harbour Circulation

The Harbour is very dynamic, and a weak thermocline develops in the Harbour during the summer. Currents within the Harbour are influenced by wind, friction, the intrusions of Lake water described below, density differences (due to temperature differences or the dissolved content of the water), the morphology of the Harbour, oscillations due to Lake Ontario water level oscillations, and the earth's rotation. The currents have been found to vary in speed and direction, with surface currents predominantly affected by wind. Under the ice, currents are generally weaker due to the drag of the ice and reduced wind drag.

The net result of this and the summer stratification is that there are substantial horizontal and vertical gradients in water quality. Hence, subtle changes in water quality are inherently difficult to detect (MOE, 1985). A high degree of small-scale variability or patchiness in the thermal, chemical and biological properties of the Harbour has been observed.

The exchange of water through the Burlington Ship Canal comprises the largest component in the water balance of the Harbour and has a major effect on water quality in the Harbour. The flow through the canal is driven by differences in water levels between the Lake and Harbour, and by differences in density (due to temperature differences) between the Lake and Harbour. Wind-driven surface drift currents may also be important at times. All of these forcing mechanisms exhibit fluctuations on a wide range of time scales, from minutes to weeks or longer. As a result, the flow in the canal is itself highly unsteady with frequent flow reversals. As well as being unsteady, the velocity profiles within the channel exhibit complexity with depth, particularly under conditions of thermal stratification during summer. The temporal and vertical spatial variability make accurate gauging of discharge in the canal difficult. As a result, uncertainty surrounds the basic water budget for the Harbour.

Several investigators have estimated the residence time for water in the Harbour (Kohli, 1984; MOE, 1985; Klapwijk and Snodgrass, 1985). While the results are quite variable, the general pattern is indicative. That is: if only watershed runoff is considered to be flushing the Harbour, the residence time would be about 500 days; if runoff plus the STP inputs are considered, the residence time is between 300 and 350 days; but when the Ship Canal exchange is also taken into account, the residence time drops to 90 days. Hence the Lake-Harbour exchange is crucial to water quality in the Harbour. The monthly pattern of flows given by Klapwijk and Snodgrass (1985) have a distinct peak from July to October, while Kholi's (1984) flow pattern data show a peak in early summer. Clearly it is difficult to estimate the Harbour-Lake exchange, but the process is significant.

The rate at which the Harbour is flushed by cleaner Lake Ontario water provides the simplest index for water quality considerations. However, the calculation of a flushing time or retention time is meaningful only if a water body mixes completely with the flows used in the flushing time calculation. If the flows are short-circuited from their point of inflow to the Harbour outlet without completely mixing with the main body of the Harbour, the flows will have less impact on concentrations within the Harbour. Short-circuiting can occur in two ways. Under some circumstances, flow from the Hamilton and Burlington STPs could follow a path along the eastern shoreline directly to the Harbour outlet without first extensively mixing with the main body of the Harbour (Figure 5) (Barica, 1989). Obviously, this would be beneficial for the Harbour, but would result in higher concentrations of the STP effluent in the outflow plume from the Harbour to Lake Ontario. The second short-circuiting mechanism involves the oscillation of the Lake-Harbour exchange, as exhibited by the frequent flow reversals in the Burlington Ship Canal. The measurement and explanation of the periodicities associated with these oscillations has been a subject of several studies (MOE, 1974, 1977a; Freeman et al., 1974; Palmer and Poulton, 1976).

It is clear that Lake water enters the Harbour. Evidence for the presence of intrusions of oxygen-rich lenses of water between the Harbour entrance and the middle of the Harbour, has been noted by several investigators (Figure 6a, b) (Harris et al., 1980a; MOE, 1975, 1977a, 1985; Spigel, 1989). The frequency with which Lake water forms an underflow in the Harbour is of considerable importance for Harbour water quality. No concurrent study of water temperature profiles at either end of the canal has been made, but data from MOE (1985) for temperatures in the Harbour, and from Dobson (1984) for Lake Ontario, indicates that underflow may be frequent and may occur at any time of year. The dominant pattern of Lake-Harbour exchange may thus be one in which water from Lake Ontario enters the hypolimnion of the Harbour, displacing Harbour water upward, with water from the epilimnion of the Harbour comprising the outflow from the Harbour.

Landfilling around the perimeter of the Harbour can also affect the pattern of Lake-Harbour exchange. The results of Freeman et al. (1974) and Dick and Marsalek (1973) have shown that the duration and magnitude of flows from Lake Ontario to the Harbour depend on the surface area of the Harbour. Decreasing Harbour surface area decreases the total annual volume of inflow from the Lake. Dick and Marsalek state that landfilling from 1926 to 1972 resulted in a decrease in Harbour surface area of approximately 25%. They estimate that, consequently, the total volume of the Lake water entering the Harbour annually decreased by approximately 3.2×10^8 m^3 over that period. Moreover, percentage decreases in surface area and annual inflows were roughly equal, and therefore the 25% decrease in surface area given above resulted in an estimated 24% decrease in inflow volume from 1.35×10^9 m^3/year to 1.03×10^9 m^3/year. (This latter figure is roughly equal to the 1.04×10^9 m^3/year for Lake inflow deduced from Klapwijk and Snodgrass's figures cited earlier). Dick and Marsalek concluded that further percentage decreases in Harbour surface area would result in roughly equal percentage decreases in Lake inflows.

Figure 5 Approximate exchange zone of Hamilton Harbour (shaded) affected by dilution of Lake Ontario water, estimated from ammonia-N. Arrows indicate major nutrient loads.

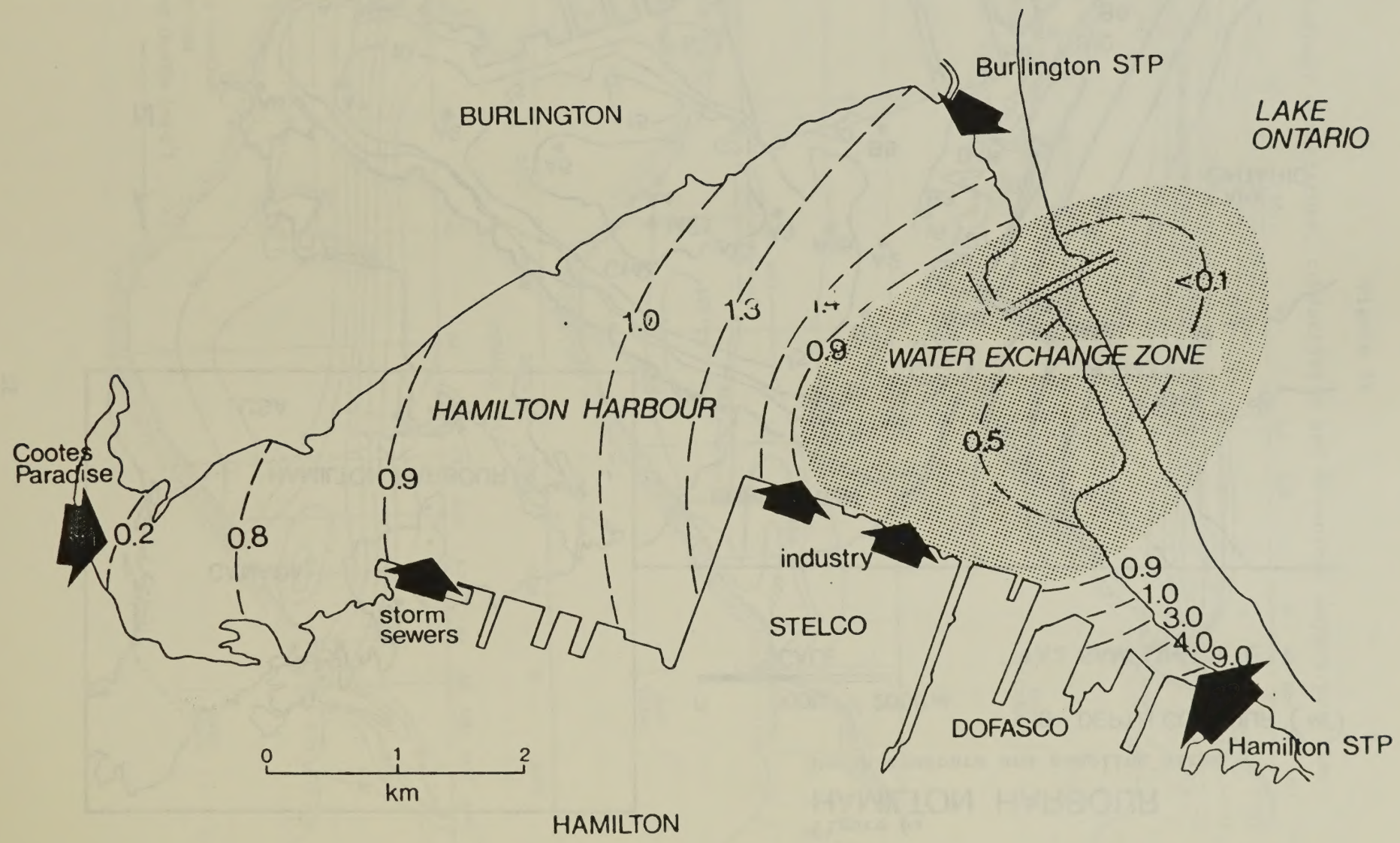


Figure 6a

HAMILTON HARBOUR

Depth contours and sampling sites

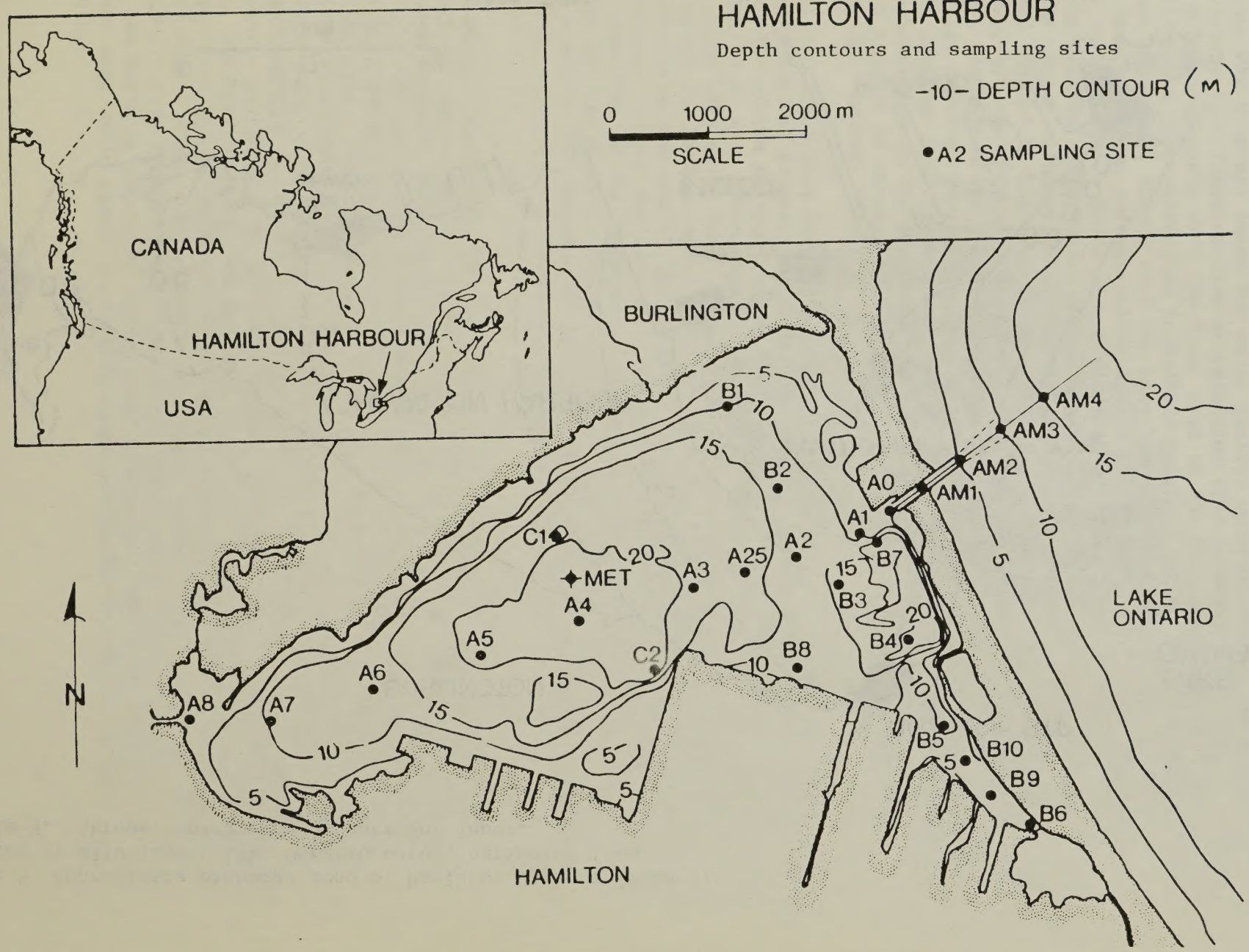
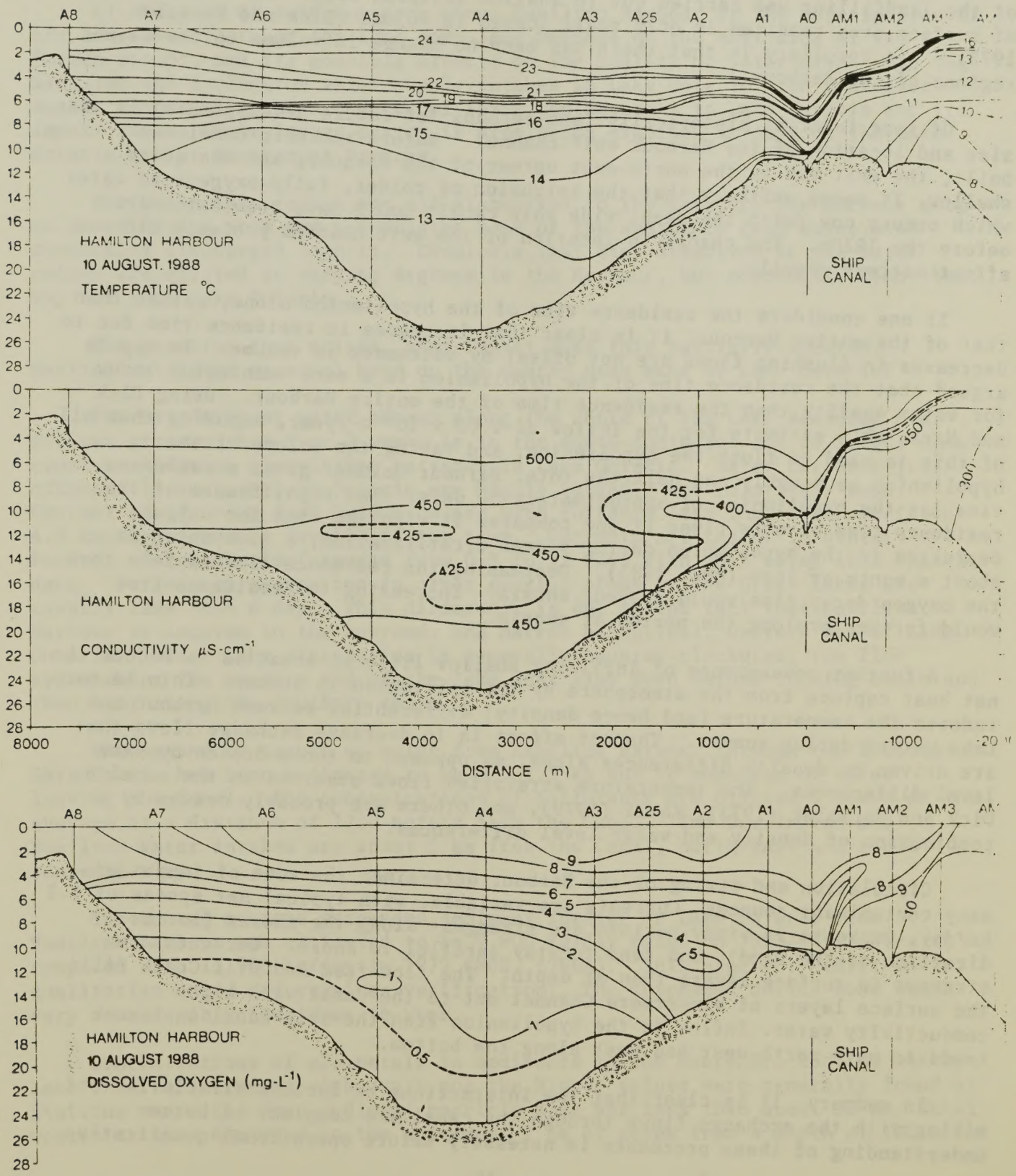


Figure 6b

Hamilton Harbour temperature, conductivity and dissolved oxygen profiles



The question arises, then, as to the effect of decreasing Lake inflow on Harbour water quality. The change in residence time is dominated by the change in flow rate, and that the relative change in volume is very small because most of the landfilling was carried out in shallow littoral areas where large losses of surface area resulted in only small losses in volume (Dick and Marsalek, 1973). (A corollary is that there has been no change in volume to the deeper regions of the Harbour.)

Of some interest historically (and perhaps for future developments) is the size and location of the Harbour exit channel. Before the ship canal was built, the exit was in the north-east corner of the Harbour, and was quite shallow. It seems unlikely that the intrusion of colder, fully-oxygenated water which occurs now (with the deep, wide ship canal) could have been extensive before the 1820s. The change in location of the exit channel probably did not affect matters greatly.

If one considers the residence time of the hypolimnion alone, rather than that of the entire Harbour, it is clear that increases in residence time due to decreases in flushing flows are not offset by decreases in volume. It may be argued that the residence time of the hypolimnion is a more meaningful index for water quality than the residence time of the entire Harbour. Using Dick and Marsalek's estimate for the inflow of 1.03×10^9 m^3/year, assuming that all of this is used to flush the hypolimnion, and taking the volume of the hypolimnion as roughly one half the total Harbour volume, gives a residence time for the hypolimnion of approximately 50 days. The significance of the residence time becomes clear if one compares it with the time for oxygen depletion in the hypolimnion during summer stratification, a time which is about a month or less (MOE, 1985). Decreasing the residence time to less than the oxygen decay time would prevent anoxia. Increasing the residence time would further prolong the period of anoxia.

A further consequence of infilling shallow littoral areas is to reduce the net heat capture from the atmosphere by the epilimnion in summer. This in turn reduces the temperature (and hence density) differential between Harbour and Lake waters during summer. The net effect is to decrease exchange flows that are driven by density differences alone, as opposed to those driven by water level differences. The temperature stratified flows observed in the canal by Dick and Marsalek (1973), Kholi (1979), and others are probably driven by a combination of density and water level differences.

Circulation and mixing of the Harbour determines the zone of impact of many contaminant sources. Currents are variable, with typical net speeds of 1-2 km/day. Currents in windy periods are strongest along the shores (in the direction of the wind), and tend to stay parallel to shore. Currents are stronger in surface layers than at depth. The flow from Red Hill Creek fills the surface layers of Windermere Channel out to the Canal with high conductivity water. Inflow to the hypolimnion from the ship canal in summer tends to move north-west and west along the bottom.

In summary, it is clear that the interactions of Harbour circulation and mixing with the exchange flows through the canal are complex. A better understanding of these processes is necessary before operational quantitative

predictions of water quality can be made.

III.1.2 Impact of Hamilton Harbour on Western Lake Ontario

At the root of many concerns about Hamilton Harbour is the anticipation of its adverse effects on the long open-lake beaches on the east side of the "beach strip", and its possible effects on the quality of water drawn into the Hamilton and Burlington water supply intakes in Lake Ontario. On a broader scale, concern for the discharge of toxic contaminants to Lake Ontario and its impact on the whole larger system is also being examined as part of the Lake Ontario Toxics Management Program.

Wastes in this region are all discharged to the Harbour. The Harbour acts as an oxidation pond and accumulates some of the sediments (and associated chemicals) discharged into it. Chemicals that stay dissolved in the water column are diluted to varying degrees in the Harbour, but eventually find their way out into Lake Ontario.

The question then arises, what impact does this partially-diluted, partially-treated material have on the nearby uses made of Lake Ontario?

The net drift of water masses along the shore of the Lake measured over periods greater than 1 or 2 weeks is to the south-southeast due to large, slow counter-clockwise circulation patterns in Lake Ontario. Water currents just offshore in western Lake Ontario are highly variable and relatively weak. Current speeds vary from 0-12.8 cm/sec with currents less than 5 cm/sec (about 4.5 km/day) observed for 58% of the time. Currents are faster in winter. Periods of "stagnation" ranged from 0.5 to 12 days with most being less than 5 days. Periods of stagnation in other coastal areas of the Great Lakes are usually less than a day. This difference is due to the fact that Hamilton Harbour is located in the extreme, and narrow elliptical, western end of Lake Ontario. Since Lake circulation is generally counter-clockwise, the flow approaching the western end of the lake must slow down before turning south and then east along the southern shore.

The extent of travel of water from Hamilton Harbour through the Burlington Ship Canal, has been estimated to be 0.5-1.5 km due to momentum of water leaving the Canal. The concentrations of pollutants are diluted 9 times on the average at a distance of 1250 meters from the Canal. The Burlington and Hamilton water intakes are about 5 km from the Canal, north-east and south respectively.

The annual average suspended sediment loading to Lake Ontario from Hamilton Harbour was estimated to be 9,800 kg/day based on 1983/84 studies, compared with 15,900 kg/day in 1979 (MOE, 1986a). This apparent reduction is qualitative only, and requires verification. The suspended solids load could vary considerably from year to year.

Concentrations of all metals in sediments in the nearshore zone of western Lake Ontario increased with depth and the higher values were generally found at stations where the mean sediment particle size was less than about 50 µm. Metal concentrations measured in the uppermost 1 cm of cores from a depth of 100 m in

the Niagara Basin zone were 3-20x more than in the nearshore zone. These distributions appear to suggest that metallic discharges from Hamilton Harbour may not have a significant impact on the sediment quality in the area immediately adjacent to the Burlington Ship Canal. This is consistent with studies which indicate that most trace metals are exported from the Harbour in association with fine particles which would have a short residence time in the nearshore zone (MOE, 1986a).

Results of sequential extraction analysis on sediments collected in 1982/83 (to identify the geochemical forms of metals) suggest that metals are less bioavailable outside the Harbour than inside (MOE, 1986a). However, a 1983 study comparing sediments from outside the Harbour to those from Windermere Basin showed this difference to be relatively slight (MOE, 1987a).

PAH analysis on sediment samples from outside the Harbour showed that the PAH concentrations depended upon the distribution of fine-grained sediment particles in a fashion similar to total metals. Based on the pattern of PAH concentrations in the sediments, there appears to be a second source of PAHs to the east of the Burlington water intake (MOE, 1987a).

Analysis of material collected in sediment traps within the Harbour during 1987, and future measurements of the quality and quantity of suspended material entering and leaving the Harbour will clarify the effects of the Harbour on Lake Ontario.

The Hamilton and Burlington water intakes were sampled regularly from May 20 to September 1, 1982 and the water chemistry was compared to offshore water and Harbour plume water chemistry. Burlington water intakes had consistently higher copper concentrations than either the offshore or Harbour plume water suggesting a local source of copper. Ammonia concentrations were elevated in 6 of 23 samples from the Hamilton water intake and 4 of 21 samples from the Burlington intake. It appears that only one day of this elevated ammonia concentration was caused by Hamilton Harbour (MOE, 1986a). The other days can be explained by local loadings, storm events and resuspension phenomena. The occasional elevations of trace metal concentrations also appear to have been from sources other than Hamilton Harbour. Therefore of the 21 or 23 days studied, only on one day was the Hamilton water intake apparently influenced by the plume from Hamilton Harbour. The dilution of the plume by a factor of at least nine with Lake Ontario water and the fact that Hamilton Harbour water itself has not exceeded the Provincial Water Quality Objectives for the last two years would suggest that the possible impact of the Harbour plume on the two water intakes is not a concern at this time. The Provincial Drinking Water Quality Program has monitored both intakes for several years and there is very little evidence of impact on water quality by Hamilton Harbour (MOE, 1988b, c).

Bacteria sampling in the Confederation Beach area confirms the drinking water intake observations. Elevated bacteria counts are a result of local sources and not a result of the Hamilton Harbour plume. Runoff from creeks during and after rainfall events seems to be the most probable source of bacterial contamination. Since the fecal coliform counts in Hamilton Harbour are now much reduced, the plume is probably not responsible for beach closures adjacent to the Canal in Lake Ontario.

III.2 Water Quality

III.2.1 Eutrophication

The concentrations of ammonia and nitrate in the Harbour affect fish and exceed the requirements for the growth of algae. Ammonia concentrations are a function of loadings versus biological processes and flushing losses to Lake Ontario. The important biological processes are algal uptake and bacterial nitrification (the conversion of ammonia to nitrate); both depend on temperature. Therefore, ammonia concentrations are high in the spring due to accumulated loadings during the winter, and the lack of nitrification and algal uptake. In the spring of 1985, ammonia concentrations in the centre of the Harbour were approximately 2000 µg/l (as Nitrogen). The concentration decreased with the onset of warmer temperatures to average values of 300-400 µg/l during summer. Average nitrate concentrations during the early 1980s were 1700 µg/l. Nitrate concentrations begin the season at the average concentration and then increase through spring and early summer due to the nitrification of ammonia to nitrate. The concentration then decreases through the summer and fall, presumably due to algal uptake and reduced nitrification rates.

Total phosphorus concentrations in 1985 declined from a May high of 87 µg/l to an October low of 37 µg/l. The seasonal average concentration was 64 µg/l. Filtered reactive phosphorus, which is generally believed to be a readily available form of phosphorus to algae, had a seasonal average concentration of 24 µg/l. A summer decline of the reactive phosphorus was apparent during 1986 and 1987.

The summer chlorophyll a concentration (a measure of algal abundance) in the surface waters of the Harbour was 27 µg/l in 1985. The seasonal average for all stations at all depths was 13.5 µg/l. The Janus-Vollenweider model relating phosphorus loading and basin retention times to the annual average chlorophyll concentration suggests that the chlorophyll concentration in the Harbour is similar to other lakes around the world, provided the total phosphorus concentration remains below 70 µg/l (Janus and Vollenweider, 1981). There has been little relation between seasonal average chlorophyll and the seasonal average phosphorus concentration during the past decade. Chlorophyll concentrations have averaged between 13-18 µg/l while total phosphorus concentrations have averaged between 40-100 µg/l (Figure 7). The soluble reactive phosphorus half-saturation constant for modelling algal growth in Hamilton Harbour is 10 µg/l (Ng, 1981). From 1984 to 1986, soluble reactive phosphorus (SRP) averaged 13 µg/l but during 1987, SRP averaged only 2.5 µg/l in the surface waters at the centre of the Harbour. According to the model, the recent low phosphorus concentrations would be one of the factors limiting algal growth.

Water clarity, as determined by Secchi disc transparency, was an average of 1.4 meters in 1986. Shoreline Secchi disc transparencies averaged 0.95 m but only the first 100 meters from shore had these reduced transparencies. Any

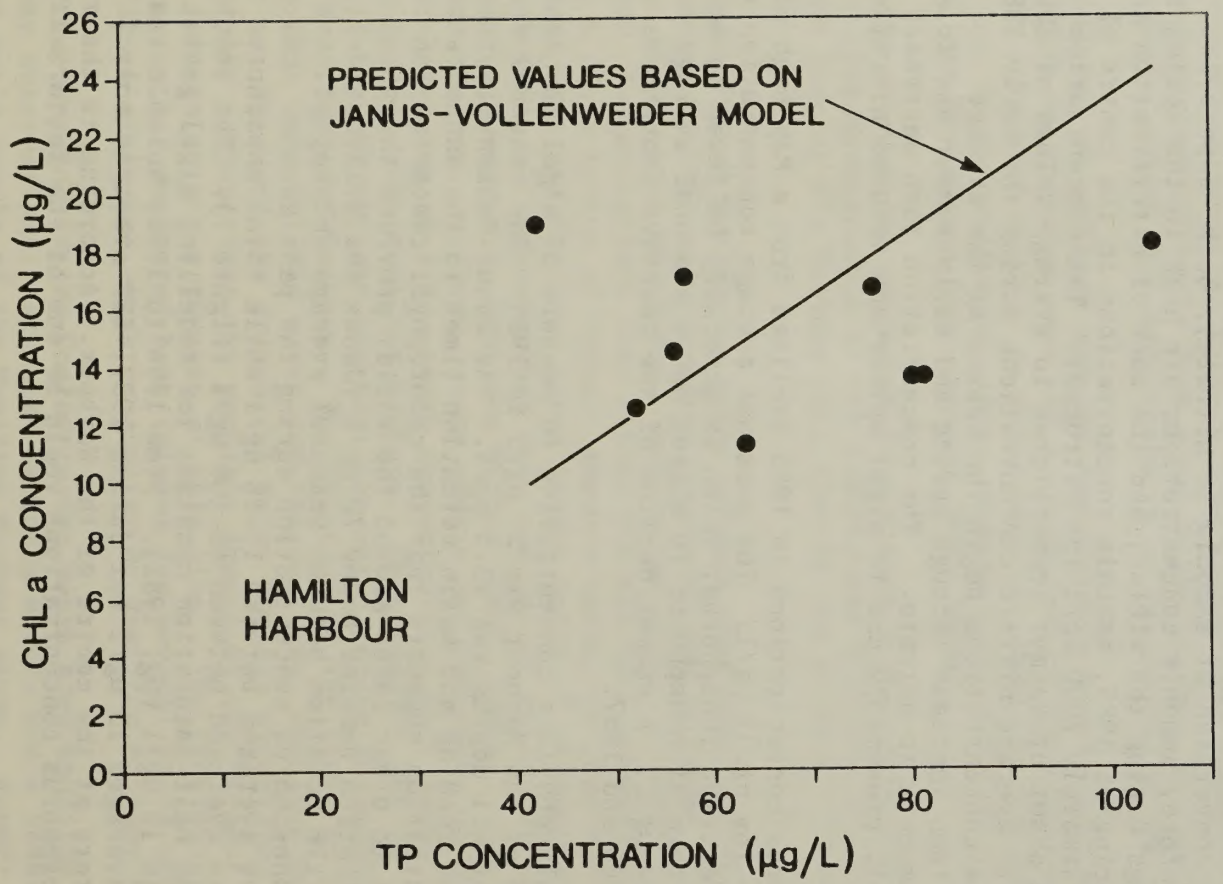


FIGURE 7. TOTAL PHOSPHORUS CONCENTRATION vs CHLOROPHYLL a CONCENTRATION

location with water depths greater than 2 m had a water clarity similar to offshore water clarity. If water clarity was solely a function of algal biomass, the Secchi disc transparency would be predicted by the OECD empirical model to be between 1.5-2.5 meters. Carlson (1977), however, predicted a Secchi disc transparency of only 0.8 -1.3 m with the current chlorophyll a concentrations. Harris and coworkers (1979a) examined the relationship between chlorophyll and water clarity as determined by light extinction through the water column and observed a relationship in four out of five years. However, chlorophyll explained only 11-30% of the variability in light extinction (Harris et al., 1979a; Sephton and Harris, 1984). Other factors such as suspended silt and dissolved substances causing colour are postulated to also be responsible for the reduced Secchi disc transparency.

Dissolved oxygen rapidly declines from saturation in early spring to values of 7 mg/l (80% saturation) in the epilimnion and 1-2 mg/l (10-20% saturation) in the hypolimnion during summer. Continuous monitoring of the hypolimnetic oxygen has shown the impact of oxygen-rich Lake Ontario water which flows into the hypolimnion causing the oxygen concentration to oscillate daily between near anoxia to 2 and sometimes 4 mg/l (Figure 8) (MOE, 1975). Oxygen levels remain below saturation in the fall, in both the epilimnion and hypolimnion, due to the breakdown of stratification of the water column and the mixing of poorly-oxygenated hypolimnetic water throughout the water column. The oxygen concentration varies considerably at any date from station to station and year to year. Oxygen isopleths suggest that anoxia may be reached within one-half meter of the Harbour sediments but rarely does the hypolimnion have less than 0.5 mg/l of oxygen. The thermocline, normally located at 6-7 meters, is unstable due to Lake-induced oscillations. Perturbations of several meters have been observed in the depth of the thermocline over short periods of time. Low saturation water can then come within a few meters of the water's surface or move into shallower areas not normally much below saturation.

Ng (1981) examined the processes responsible for depleting oxygen in the hypolimnion in summer. He concluded that nitrification of ammonia accounted for 40%, plankton decay for 40%, and sediment oxygen demand for the remainder.

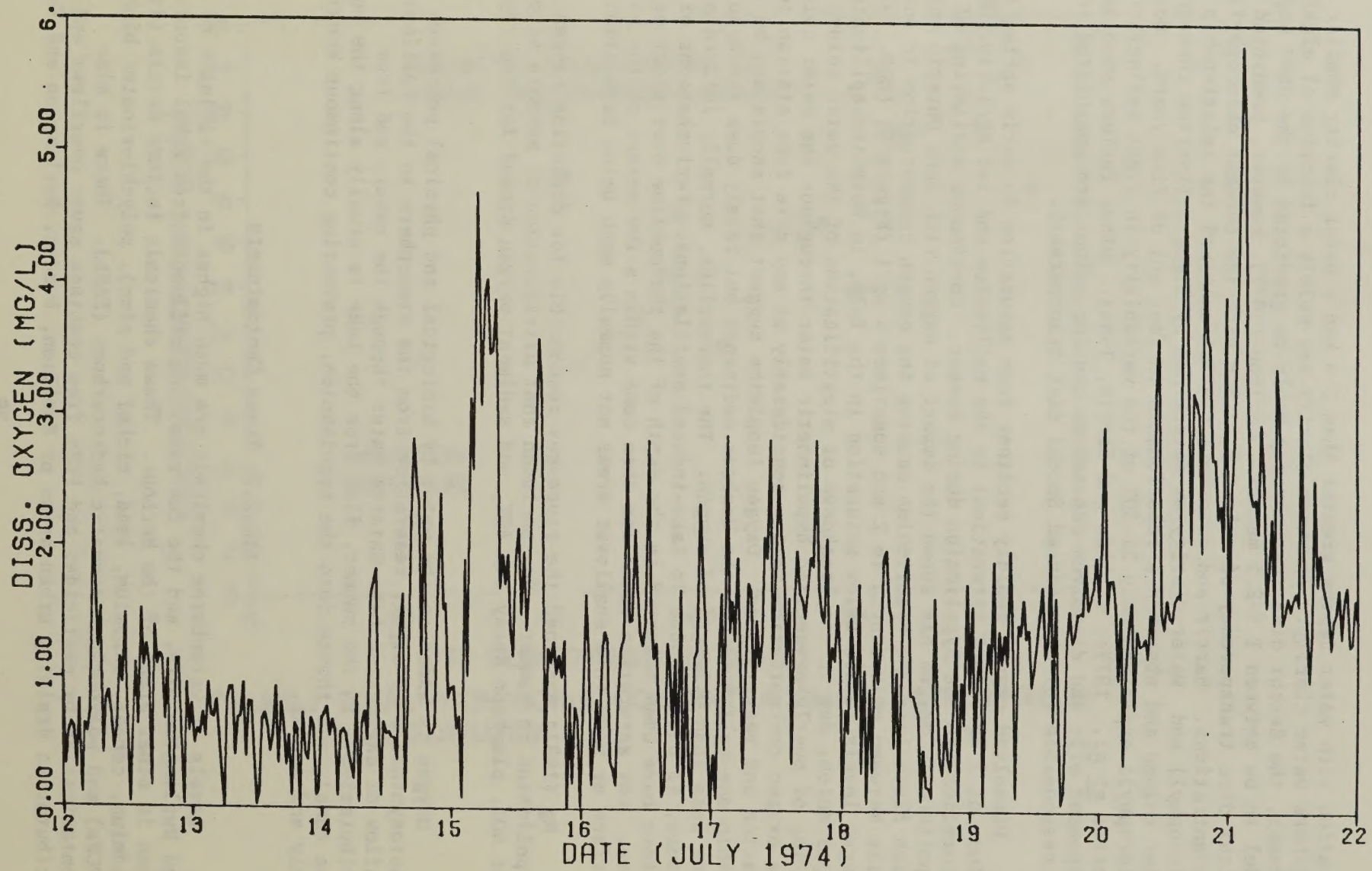
Oxygen is added to the water by biological and physical processes such as photosynthesis by algae, reaeration from the atmosphere to the epilimnion, the inflow of oxygenated Lake Ontario water through the canal, and from tributaries. In the summer, flow from the Lake is usually along the bottom of the canal, and thence into the hypolimnion, preventing continuous anoxia in July and August.

III.2.2 Trace Contaminants

Levels of waterborne chemicals are much higher in the vicinity of Hamilton and Burlington STPs, and the few remaining effluents from steel industries, than in other areas of the Harbour. These chemicals include metals (iron, cadmium, copper, chromium, lead, nickel and zinc), polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs). There is also contamination by pesticides and PCBs from combined sewer overflows and from tributaries draining urban areas of Hamilton, Dundas, Burlington and Waterdown.

Figure 8

Dissolved oxygen in hypolimnion of an offshore location in Hamilton Harbour



From 1962 to 1985, the industrial loadings of conventional pollutants to the Harbour have been reduced 60-95%. From 1977 to 1983, the concentration of BOD in the water column decreased from 3.39 to 3.09 mg/l, although these values relate more to phytoplankton densities than to direct discharge of BOD.

Metals

The majority of metal loadings are from the steel industries. Consequently, concentrations of metals are most elevated in the mixing zones around the discharges. The average concentrations meet Water Quality Objectives (Table 6).

TABLE 6: Average concentrations of trace metals in Hamilton Harbour water in 1982 and 1984-87 (µg/l). Also shown are the Provincial Water Quality Objectives (PWQO), and the percent of samples that exceeded these Objectives.

Metal	Concentrations		PWQO	% Exceedences		
	1982	1984-87		1982	1984-87	86-87
Copper	7.6	3	5	69	11	<1
Nickel	7.2	4	25	4	1	<1
Zinc	23.3	17	30	30	6	2.7
Cadmium	<0.2	ND	0.2	19	9	0
Lead	4.8	ND	25	1	0	0
Iron	248.3	191	300	33	15	9
Manganese	56.2	82	N/A	-	-	-
Mercury	0.07	N/A	0.2	2	-	-
Arsenic	<1.0	N/A	100	0	-	-

ND: Not detected.
N/A: Data not available.

Loading reductions from the iron and steel industries, implemented in 1983/84 and continuing today, have translated into decreased concentrations of trace metals as well as decreased frequency of exceedences of the Objectives. The exceedences are generally not large and the high levels of total organic carbon probably mitigate toxicity to most biota through complexation. The concentration of copper has declined to the point that Lake Ontario water flowing into the Harbour has similar concentrations of copper and similar frequencies of exceedences (MOE, 1986a). Except for iron, few exceedences of the Water Quality Objectives for trace metals have been observed since 1985. Iron is occasionally released from the bottom sediments during summer and exceedences of the iron Objective were observed in the hypolimnetic water only.

Organics

Oil and grease are the largest volume organic materials discharged to the Harbour. MOE (1987d) reported the industrial loadings to be 4634 kg/day in 1986. Oil and grease are released in relatively low concentrations but in high volume effluents. Sometimes an oil sheen appears on the water surface in areas

close to the discharges, affecting the aesthetic aspects of Harbour use. While little direct toxicological significance is attached to this discharge, it remains of some concern.

Phenol discharges from industries have decreased by 96% since 1965 and levels in the Harbour are now below the Objective (1 µg/l). Previously, average levels had been as high as 10 - 50 µg/l. The current levels of phenols represent no threat to aquatic biota.

PCBs and pesticides were sampled on six occasions in 1982 at six stations (Poulton, 1987). The butylated hydrocarbons (BHCs) (α, β, γ) and hexachlorobenzene (HCB) were the most frequently found organic contaminants (92, 14, 69, and 25% of samples analysed, respectively). α-BHC was evenly distributed seasonally and spatially in the Harbour, and is also detected throughout Lake Ontario. Point source loadings of α-BHC are probably not significant in Hamilton Harbour, given the universality of the compound. γ-BHC is the only BHC which has a Provincial Water Quality Objective (10 ng/l). The median concentration of γ-BHC was 8 ng/l and 14% of the water samples had concentrations exceeding the Objective. PCBs were measured using a method with a detection limit of 20 ng/l. Five of 36 samples (14%) exceeded this detection limit. Since the Objective is 1 ng/l, PCBs may have exeeded the Objective in between 14 and 100% of the samples (MOE, 1985). Endosulfan sulphate, heptachlor epoxide, and oxychlordane were detected in only 3, 3 and 6% of the samples and no exceedences of Objectives occurred. Aldrin, α- and γ-chlordane, dieldrin, methoxychlor, endosulfan I and II, endrin, heptachlor, mirex, and DDT and its metabolites were not detected.

Historically, Hamilton Harbour water has not been analysed for PAH compounds. It is thought that loadings of these compounds were high in the Harbour, but that significant reductions have occurred. The best estimates suggest that current loadings are approximately 1.8 kg/day. Concentrations of PAHs in suspended particulates were 3.3 - 5.5 µg/g. Calculations of total PAH concentrations in the water column, based on particulate concentrations of PAHs and knowledge of phase separations (70-95% dissolved phase) and typical Hamilton Harbour particulate concentrations (10 mg/l), suggest that total PAH concentrations in the water column are approximately 0.15-0.88 µg/l. PAHs decompose in the water column primarily through sunlight. The half-life of this process is in the order of hours.

Although persistant trace organics have a high affinity for particulates in the water column, much of the total mass of organics may be in the dissolved phase because of the relatively low concentration of particulates. The dissolved phase referred to here is defined as the water which has been filtered through a 0.45 micron filter, through which collodial material and macromolecules will pass. Trace organics are hydrophobic and will become adsorbed to particulates such as soil particles and collodial particles. Due to the low concentration of large particles in the water column, the majority of hydrophobic organic compounds will remain in the dissolved phase or become attached to collodial material. Since collodial particles will not settle out of the water column due to their small size, for all practical purposes collodial material and any associated organic contaminants are considered to be in the dissolved phase.

III.3 Sediment Quality

III.3.1 General Description

Postglacial sediments in the Harbour are derived from tributaries, municipal and industrial discharges, and sewers. Settlement and urbanization have increased sediment loads, compared with presettlement conditions, by increasing sediment production (e.g. construction and farming activity) and by altering basin hydrology (e.g. channelization, creation of impervious land surfaces).

Existing data (MOE, 1985; Poulton, 1987) suggest that a large zone of similar sediments covers the entire deep-water area of the Harbour except the far east end. Pollutants have been gradually mixed and transported towards the deep central basin. Other distinct zones occur near the Burlington Ship Canal, where the effects of Lake-Harbour exchange are important, and along the north shore, where shallow-water silty sediments with lower pollutant concentrations are found. Shallow locations close to the major outfalls represent individual zones related to the nearby discharges. The west end is distinct due to the influence of Cootes Paradise and Grindstone Creek. Most of the surficial sediments in Hamilton Harbour are gray to black, and rich in silt and clay. Sandy sediments are found along the north shore, near the Ship Canal, and at the entrance to Cootes Paradise.

Temporal trends in contaminant concentrations in surficial sediments (Table 7) are difficult to assess due to variations in sampling and analytical methodologies. Available data are inconclusive as a means of tracking loading reductions (suspended solids, nutrients, metals) at municipal and industrial discharges. Chemical analysis of sediment cores obtained at 22 locations throughout the Harbour during 1987 will assist in the interpretation of temporal trends. These data are not yet available.

TABLE 7: Trace metals in suspended solids and surficial sediments (1980 and 1986). Iron and manganese in mg/g, all others in µg/g.

Metal	Suspended Particulates		Surficial sediments	
	1980	1986	1980	1986
Iron	35	53	68	74
Manganese	20	9.6	1.9	2.1
Zinc	1050	1797	2700	2180
Lead	192	307	310	281
Copper	103	105	130	158
Cadmium	-	6.3	5.7	14.1
Nickel	50	52	66	55

III.3.2 Sediment Sources

Suspended sediment loads to the Harbour were estimated to average 140,000 kg/day in 1977, diminishing to 66,100 kg/day by 1985 (MOE, 1985) and 50,150 kg/day in 1987. This apparently large decrease will be confirmed during future investigations as part of a regular surveillance program.

The Ministry of Environment (West-Central Region) is carrying out a study to determine sources and loadings of suspended sediments and total phosphorus from tributary inputs to Hamilton Harbour. A weekly sampling program was initiated on June 16, 1987 at seven locations on five tributaries: Grindstone, Redhill, Spencer, Borer's and Indian/Rambo Creeks. Sampling will be complete in the spring of 1989.

The most likely erosional areas and estimated suspended sediment inputs from the various land uses in the basin have recently been determined. These two studies will allow revision of the present estimates of suspended sediment loadings to the Harbour, the contribution of different land uses and the areas which are most prone to instream erosion. Abatement scenarios can then be determined with greater precision.

III.3.3 Eutrophication-related conditions

Sediment sampling in the Harbour over the period 1975 to 1982 identified concentrations of nutrients throughout the Harbour which are higher than the disposal guidelines. Concentrations of total phosphorus (TP) and total Kjeldahl nitrogen (TKN) were consistently above existing MOE guidelines for open water disposal of dredged material. TKN and TP averaged 3.1 and 2.9 mg/g respectively (Table 8). The loss on ignition (LOI) of the surficial sediments from 1975 to 1980 was approximately 10% compared to the MOE guideline for disposal of sediments in the open Lake of 6%.

During the summer and fall, the low dissolved oxygen concentrations in the hypolimnion and the high organic loadings to the sediments result in low redox potentials within the sediment. Manganese release from the sediments to the overlying water occurs frequently during summer and fall and iron release occurs less frequently towards the end of the summer. As a result of the reducing conditions, phosphorus release has been observed in the past. However, since the phosphorus appears to be associated with iron and the reducing conditions are not severe enough to release iron, phosphorus release from the sediments rarely occurs.

III.3.4 Trace Contaminants

Persistent Organics

Sediment samples contain up to 2000 µg/g of organic solvent extractables (Mudroch and Sandilands, 1980). Elevated levels of PCBs have been observed in the sediments from Windermere Basin due to STP and storm water discharges. Elevated PCB concentrations have also been observed along the north shore, particularly around the LaSalle Park Pier; the source is unknown. The mean concentration of PCBs in the Harbour sediments is 0.2-0.44 µg/g (MOE, 1985,

TABLE 8: Summary of chemistry of surficial sediments from 1975 to 1986, compared with the Guidelines for Open Water Disposal. All values in µg/g unless otherwise stated.

	1975	1976	May 1977	October 1977	1980	1986	Disposal Guideline
LOI (%)	10.5		9.1	9.5	9.8		6
BOD (mg/g)	3.9		2.6				
SOD (mg/g)	152	140	150	150			50
NH_3			30	10			100
TKN (mg/g)	3.5	2.7	2.9	2.9	3.5		2
TP (mg/g)	3.4	2.4	2.7	2.9	3.2		1
Ether Ext. (mg/g)			12.5	7.6			1.5
Iron (mg/g)	68	70	88		68	74	10
Copper	101			110	130	158	25
Chromium	206	200		220	204		25
Nickel	45	39		52	44	55	25
Zinc (mg/g)	3.1	2.0	2.6		2.7	2.2	0.1
Lead	320	260	310	300	310	281	50
Cadmium	7.8	5.0		6.3	5.7	14.1	1
Manganese	1670				1900	2100	-
Mercury	2.4	0.4	0.7	0.6	0.3	2	0.3
Cobalt	15			12	10	20	50
Arsenic			19	22		40	8

1986a) which is within the range for sediments of other harbours on Lake Ontario (0.01 - 0.62 µg/g), but well above the levels in sediments offshore (0.058 µg/g). The MOE guidelines for open-water disposal of sediments contaminated with PCBs is 0.05 µg PCBs/g. Some samples from the deepest areas and along the industrial shoreline exceeded 0.5 µg/g (MOE, 1986a). In one study, the highest value (1.27 µg/g) occurred near the Burlington shoreline, and the lowest value was in Windermere Basin (MOE, 1986a). In other studies, the concentration of PCBs in Windermere basin was 10 µg/g (MOE, 1976) and 1 µg/g (MOE, 1982). The distribution of PCBs is highly variable and the apparent random distribution is not yet understood, although seasonal variability associated with resuspension events may be involved.

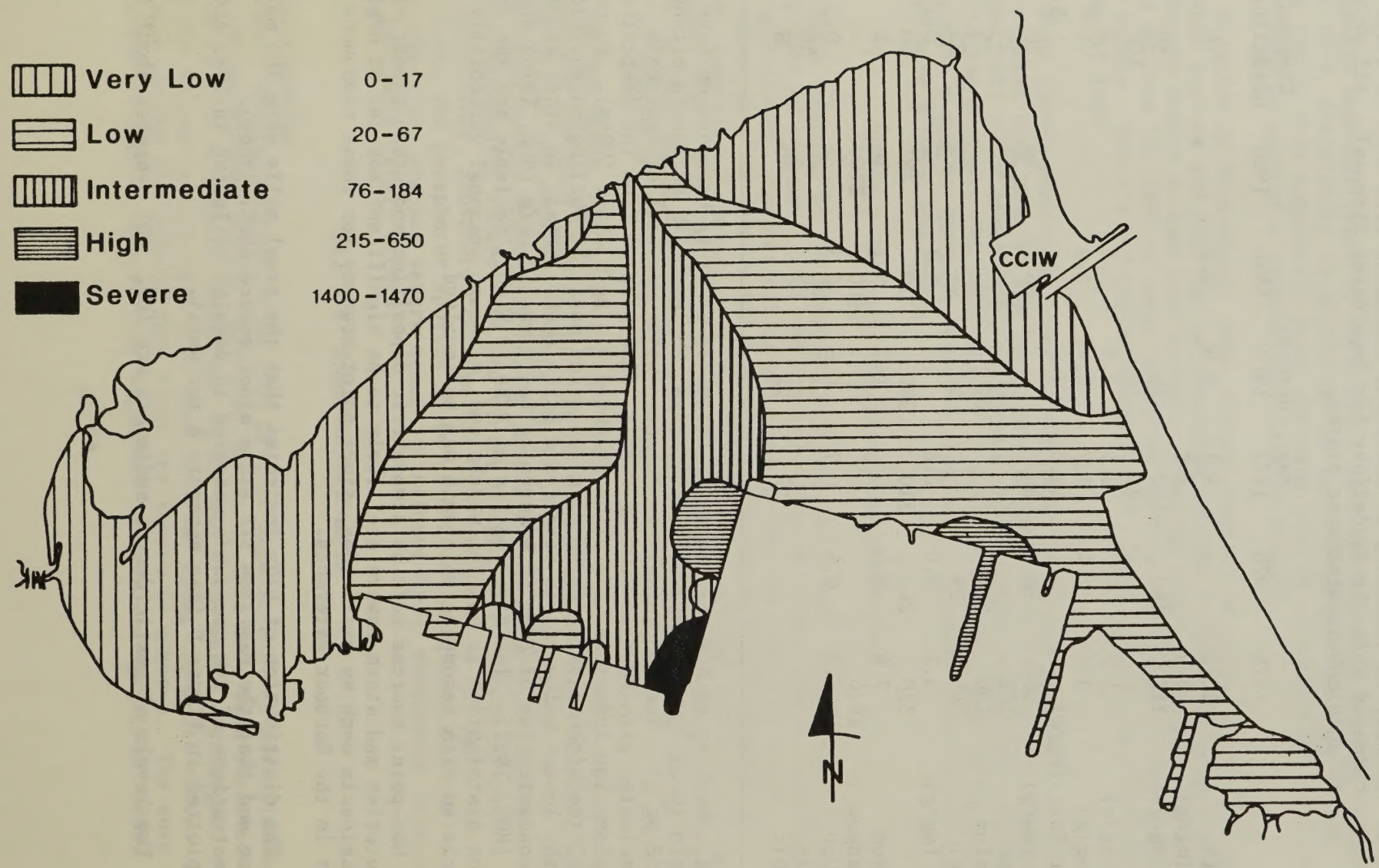
Non-point sources such as atmospheric deposition and urban runoff via tributaries and storm sewers are likely to be significant sources of organic contaminants such as pesticides since point sources for these compounds do not exist in the Harbour watershed.

The distribution of PAHs indicates that the steel mills were the main source and that the Hamilton STP was a minor source (MOE, 1986a). Concentrations of PAH compounds measured in samples collected in 1985 and 1988 are plotted in Figure 9 (see Appendix B for data).

The levels of pesticides in sediments are low. DDT averages about 6 ng/g

Figure 9

TOTAL POLYAROMATIC HYDROCARBONS (ug/g) IN HAMILTON HARBOUR SEDIMENTS



dry weight compared to 2 - 30 ng/g in other Lake Ontario harbours. Other frequently occurring pesticides were α- and β-chlordane (5 and 7 ng/g respectively) and α-hexachlorocyclohexane (α-BHC, 2 ng/g) which were found in 50-65% of the samples. HCB (<1 ng/g), op-DDT (<5 ng/g), pp-DDE (<1 ng/g), and β-BHC were found in 15-25% of the samples (MOE, 1986a) (see data in Appendix B).

Metals

Metal levels in the surficial sediments from six stations from 1975 to 1986 and the guidelines for open-water disposal of dredged material are shown in Table 8. Data on the spatial variability in trace metal concentrations in the Harbour sediments are presented in Appendix B. One example, zinc, is plotted in Figure 10 as an illustration of such distributions.

Lum and coworkers (McIsaac et al., 1982) found that the most important chemical phase for metals was the iron-manganese oxides. These oxides controlled the solubility of manganese, zinc, and occasionally lead. These elements can be released into solution and become more bioavailable and toxic if the water becomes anoxic. Most of the copper was associated with organic matter; chromium, lead, nickel and zinc were also often associated with organic matter (McIsaac et al., 1982). In many samples, a large portion of the metals was refractory; thus, the metals were not bioavailable or toxic. Mudroch (1980) found that cadmium, chromium, mercury, and arsenic were not released into solution when sediment samples were shaken with lake water.

With the exception of the area near the Dundas STP, the concentration of metals in most of Cootes Paradise is much lower than in Hamilton Harbour. Concentrations of zinc, lead, and copper are 1/8, 1/5, and 1/2 respectively, of those in the Harbour sediments (MOE, 1975, 1977b). Moreover, the concentrations of zinc, copper, lead and cadmium in the surface sediment near the outlet of Cootes Paradise decreased greatly from 1975 to 1980 (MOE, 1986). The improvements to the Dundas STP are responsible for the improvements in water quality and presumably in sediment quality of Cootes Paradise.

III.3.5 Dredging Operations

Dredging activity in the Harbour has gradually diminished since the late 1950s. Maintenance dredging, which is carried out by Public Works Canada, has removed a total of 341,573 m^3 since 1980. Capital dredging projects are undertaken by the Hamilton Harbour Commission as needed. Most of the recent activity has been in the approach channel and turning basin to the Dofasco and Strathearne Avenue slips. In addition, some slips, which had been dredged regularly in the past, are slowly being filled in to form piers. No dredging has been necessary in the Harbour since 1984.

Since 1970, disposal of the dredged material has been confined to prevent the entry of pollutants back into the watercourse. Therefore, the dredging and disposal operations probably have little negative effect on water chemistry and sediment chemistry. The dredging operations are removing contaminated sediments and therefore could be viewed as improving the Harbour sediment contaminant conditions. However, the amount of sediment dredged during the past decade is minor relative to the total amount of contaminated sediment in

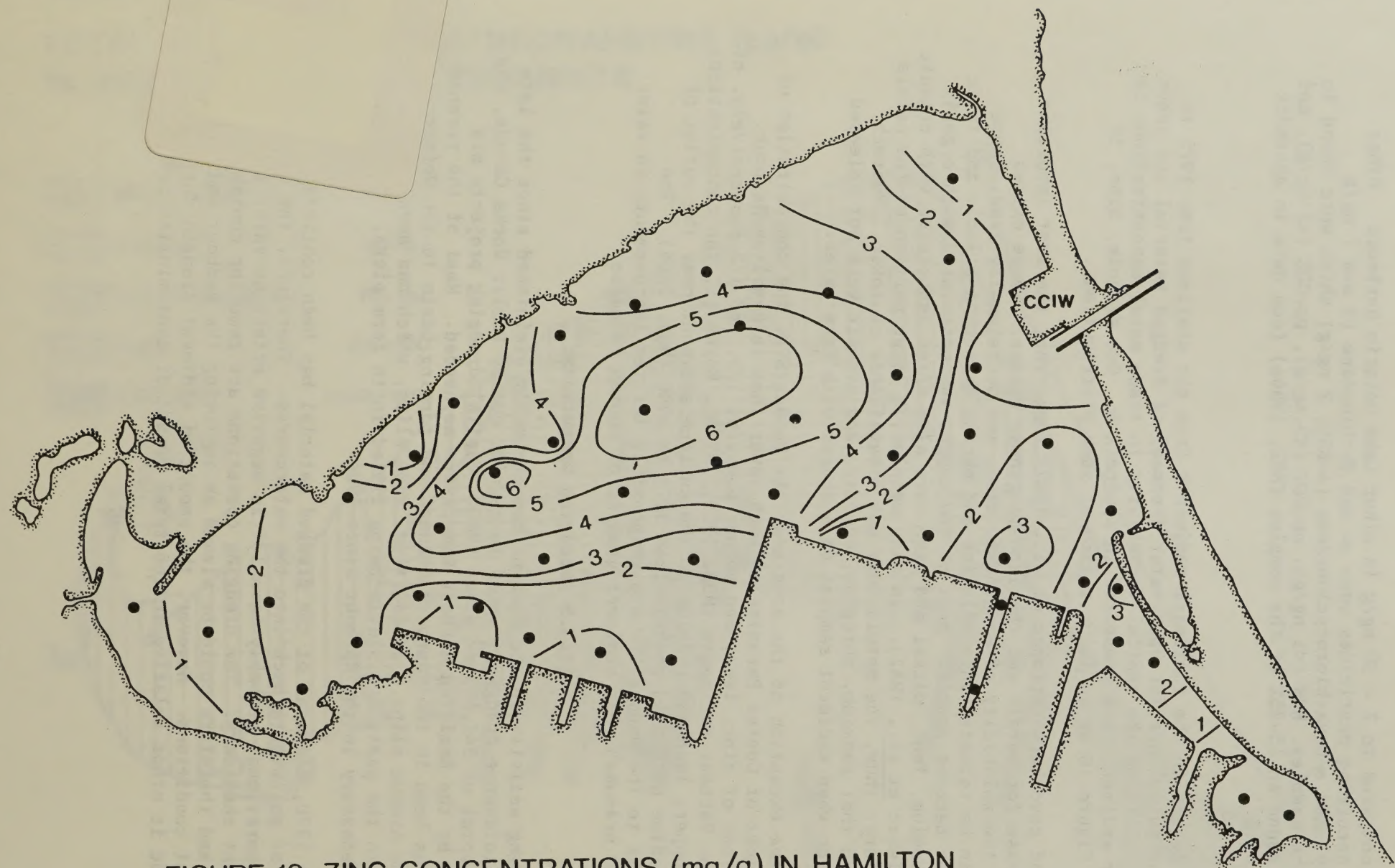


FIGURE 10. ZINC CONCENTRATIONS (mg/g) IN HAMILTON HARBOUR SEDIMENTS

the Harbour.

The Hamilton Harbour Commission has advised that the capacity of existing CDFs for dredgeate disposal for navigational needs is adequate until the year 2010. No plans have been made for adequate capacity beyond that date.

III.4 Biology

III.4.1 Bacteria

Coliforms (Objectives for Swimming)

Bacterial counts are higher in the south and east areas of the Harbour compared to the north and west. During the past decade, frequent sampling was conducted at the central (#258) and western (#270) stations in mid-Harbour, and the fecal coliforms were consistently below the objective for swimming (geometric mean= 57/100ml). Fecal coliform counts recorded in 1986-87 indicate moderate increases over those of a decade earlier. Mean fecal coliform counts based on just six samples for each station all exceeded the level set for swimming (100/100 ml). More intensive sampling would be required to reliably test the suitability of Hamilton Harbour for body contact recreation. The geometric mean fecal coliform counts (#'s/100 ml) were 114 and 175 at stations #270 and #258, respectively. Climatic conditions in 1987 (dry and hot) may have been responsible for the elevated fecal coliform counts.

Total coliforms were not determined in 1987. Previous estimates from 1975 indicate that the Harbour exceeds the total coliform objective for swimming (1000/100ml). The geometric mean for stations #270 and #258 for 1975 was 1475/100ml. The south and eastern areas of the Harbour had higher levels of total coliforms.

The first beach reconnaisance sampling for fecal coliforms was done in 1988 along the northern and western shores. The results are shown in Table 9 (S. Painter, NWRI, pers. comm.). Samples were collected in 1-1.5 m water depth by NWRI, and were analyzed by the Hamilton-Wentworth Region Laboratory. The higher values observed are related to rainfall events, either during or just before the sampling date.

TABLE 9: Fecal coliform counts in Hamilton Harbour, 1988 (counts/100 ml).

	July				August				
	4	11	18	25	2	8	15	22	29
Hager/Rambro	68	152	>2400	180	24	44	56	48	200
La Salle E.	44	84	220	320	116	24	84	60	72
La Salle W.	124	272	320	440	12	68	128	12	100
West RR	4	68	>2400	1000	80	32	64	52	36
Lax Canal opening	64	32	>2400	720	68	36	220	56	28
Lax Canal middle	104	84	>2400	280	72	76	200	20	240
Lax Canal back	248	432	>2400	400	80	136	1200	64	160

While this limited scale of samples does not constitute the normal scale of sampling done by health authorities for beaches, they present the clear possibility that remedial programs could be effective in bringing some specific areas of the Harbour within standards for a good portion of the summer. Further investigation is required if it is decided that a beach-by-beach strategy for opening up swimming opportunities is viable.

Bacteria Involved in Chemical Cycles

Annual, Harbour-wide geometric mean densities of sulphur oxidizing bacteria have changed dramatically, but irregularly, since 1975. This suggests that the significance of these bacteria and the sulphur oxidizing processes to oxygen depletion may vary from year to year. In general, densities decrease with depth and from the eastern to the western end of the Harbour. This suggests a strong link between bacterial numbers and the point source inputs. The last source of reduced sulphur was eliminated in 1984, and therefore, sulphur oxidation is probably no longer important in the Harbour.

Nitrification is a two step bacterially-mediated process which converts ammonia (NH_3) to nitrate (NO_3): first, ammonia to nitrite by Nitrosomonas; and then, nitrite to nitrate by Nitrobacter. Nitrification requires oxygen. The seasonal contribution of nitrification to the total water column oxygen demand ranges from 10% to 45%. Population densities of nitrifiers show extremely high fluctuations not just seasonally, but also on a weekly basis. The presence of significant concentrations of ammonia in the Harbour throughout the year indicates that these bacteria are not substrate limited. Populations of nitrifiers were highest in the west end of the Harbour which is geographically distant from the point source loadings of ammonia.

Heterotrophic Bacteria

Heterotrophs are a heterogeneous group of organisms requiring organic carbon for growth and oxygen for metabolic processes. Densities are greatest in the eastern end of the Harbour. Levels are elevated in the surface waters where temperature, dissolved oxygen, algal biomass and dissolved organic carbon concentrations are the highest. Heterotrophic bacteria are most abundant in the spring and autumn and least in summer, suggesting that densities are not strictly controlled by temperature. In addition, the presence of high concentrations of dissolved organic carbon throughout the year would suggest that they are not substrate-limited. The major factor limiting growth and metabolic activity during the summer would appear to be low dissolved oxygen concentrations.

III.4.2 Phytoplankton

The production of organic carbon by phytoplankton in the Harbour is up to 1.5 times greater than the organic carbon loadings from municipal and industrial sources (MOE, 1985). Much of this algal biomass settles into the hypolimnion where it decays and consumes oxygen. Together with ammonia oxidation, the oxidation of decaying algae can keep the hypolimnion anoxic (MOE, 1985).

The algal biomass in the Harbour is lower than would be expected from nutrient loadings (Haffner et al., 1980). Although Haffner proposed that physical factors regulate phytoplankton growth, others have thought that toxic compounds may inhibit algae. Algae isolated from Hamilton Harbour were not affected by zinc concentrations about 100 times higher than those observed in the Harbour (Piccinin, 1977). Wong et al. (1978) found that mixtures of metals in concentrations equivalent to the Water Quality Objectives were inhibitory to four species of algae. The metal concentrations (µg/l) used were: arsenic 50; cadmium 0.2; chromium 50; copper 5; iron 300; lead 25; mercury 0.2; nickel 25; selenium 10; and zinc 30. Current metal concentrations (µg/l) in Hamilton Harbour are listed in Table 6. Goudey (1983) found that copper and mercury at concentrations found in the Harbour could inhibit photosynthesis; but again, metal concentrations have decreased since Goudey did his study. Metals are largely detoxified by precipitation and adsorption to cell debris (Goudey, 1983). Moreover, some Harbour algae (i.e. Scenedesmus and Coelastrum) are more tolerant to copper and zinc than are similar laboratory strains (Goudey, 1983).

Analyses of algae suggested elevated levels of copper, chromium and nickel relative to sediment concentrations. However, these metals may be regulated as nutrients, i.e. they may be actively scavenged from water or excessive levels may be excreted. Concentrations of cobalt, zinc, and lead in algae were lower than in sediments.

Physical factors are probably more important in restricting algal growth. Light limitation by coloured organic material (Harris, 1976; Harris et al. 1980a) and self-shading (Harris, 1976) is a major factor regulating macrophyte and phytoplankton growth. Light limitation favours the growth of larger algae which can optimize light utilization (Harris, 1976).

Phytoplankton are sensitive to rapid fluctuations in light regime, such as those brought about by turbulence in the mixed layer (Harris et al., 1980b). Incursions of Lake Ontario water through the Ship Canal, and direct wind stirring cause vertical mixing and rapid changes in mixing depth.

Phytoplankton are adaptable to fluctuations in the ratio of light penetration to mixing depth (Haffner et al., 1980). Physiological adaptations such as altered chlorophyll content or photosynthetic enzymes are seen during the summer in green algae. Some species, such as Cryptomonas, utilize heterotrophic processes rather than relying on photosynthetic carbon uptake. Small coccoid cells such as Chlamydomonas lose their flagella and pigment as the ratio of light penetration to mixing depth decreases and cells spend less time in the euphotic zone.

During periods of stable light and mixing depth, large cells such as Oocystis borgei predominate. This species persisted in the summer once a thermal gradient was established, but declined when lake mixing increased (Haffner et al., 1980). Changes in the mixing depth can give the impression of multiple growth peaks. Near monospecific phytoplankton blooms occur most commonly under conditions of relatively stable physical parameters (Harris et al., 1980b).

Diatom growth is related to vertical mixing. Without vertical turbulence,

the heavy silica shells tend to sink out of the water column. The persistence of diatoms throughout the year is evidence of vertical turbulence during the stratified period (Haffner et al., 1980). The survival of Stephanodiscus also depends directly on its resuspension by vertical mixing (Harris et al., 1983). Diatoms are also favoured because they can utilize energy from green light more efficiently than can green algae. Since green light penetrates water three times farther than blue light, diatoms are less stressed when light penetration is poor.

The seasonal succession of Hamilton Harbour phytoplankton includes diatoms and small phytoflagellates early in the year, during periods of homogeneous mixing. These are followed by the predomination of coccoid green algae for a short period of time, and then by a mixture of diatoms and green algae when the maximum summer temperature is reached. Diatoms and flagellates later return as the dominant species. Blue-green algae are noticeably absent from the Harbour despite the eutrophic conditions (Harris and Piccinin, 1980).

Algal primary production is responsible for the fixation of 6.5 to 58 tonnes of organic carbon per day which is 0.2 to 1.7 times the estimated external load in 1979. In addition, 4.6 to 41 tonnes per day of organic nitrogen is similarly produced which is 0.2 to 1.6 times the estimated external load for 1979. Both organic carbon and nitrogen are responsible for a significant portion of the oxygen demand in the Harbour, and algal biomass is a major contributor to these reservoirs.

III.4.3 Zooplankton

The few studies that have been done on Hamilton Harbour zooplankton communities have established that the zooplankton fauna is typical of a eutrophic lake where the food chain is largely based on detritus (Piccinin and Harris, 1980; Harris, 1976). Large rotifer populations dominate the zooplankton community in the Harbour for most of the year. A cladoceran, Bosmina longirostris, is also common at certain times of the year, while some other cladoceran species (e.g. Daphnia) and copepods are less common than might be expected based on observations from other eutrophic lakes.

The seasonal succession of zooplankton in Hamilton Harbour includes an early spring peak made up almost entirely of the rotifer Keratella quadrata (Harris, 1976). During summer in the stratified Harbour, epilimnetic species are dominated by B. longirostris and Brachionus angularis. Few species can survive in the anoxic bottom layers. During fall turnover, zooplankton numbers increase as hypolimnetic reoxygenation opens up new habitats. Piccinin and Harris (1980) have found B. longirostris abundance to be positively correlated to oxygen tension during the summer. In 1976, MOE aerated two sites in the Harbour, creating an oxic hypolimnion, leading to an increased zooplankton biomass when compared to the previous year (Piccinin, 1977).

Zooplankton biomass has been positively correlated to phytoplankton biomass in the epilimnion of Hamilton Harbour (Harris, 1976). Fluctuations in zooplankton numbers and dry weights were found to correspond to changing phytoplankton biomass, and to the thermal structure of the water. Grazing, however, had little effect on total algal biomass (Harris, 1976). It is

believed that the zooplankton in the Harbour feed mostly on bacteria and detritus (Piccinin and Harris, 1980).

Rotifer distribution was shown to be associated with both seasonal and depth components (Piccinin and Harris, 1980). Rotifer abundance was correlated with ammonia and silica distribution which vary with the season and with depth. Rotifers generally occur throughout the entire water column.

III.4.4 Benthos

Johnson and Matheson (1968) sampled the benthic community of Hamilton Harbour in 1964. Their results indicated a severely degraded ecosystem dominated by pollution-tolerant oligochaetes (worms). Limnodrillus hoffmeisteri occurred at all of the sites sampled and represented 50% of the total mature population of oligochaetes. Tubifex tubifex was found at 85% of the sites and contributed 30% to the population. More sensitive species such as Quistadrillus multisetosus made up less than 5% of the population and occurred at less than 30% of the sample sites. Oligochaete abundance was highest in the area adjacent to the Burlington Ship Canal suggesting a positive effect of Lake Ontario on Hamilton Harbour water and/or sediment quality. Low abundance in the rest of the Harbour, particularly in a 2 km^2 "toxic zone" close to the Ottawa Street slip, supported the hypothesis that poor water quality and/or sediment toxicity was inhibiting the abundance and distribution of oligochaetes in the Harbour.

The Harbour was resampled in 1984 to determine the response of the benthic community to remedial actions implemented between 1964 and 1984. The Harbour was again dominated by oligochaetes. Abundance ranged from absent at the south end of the Ottawa St. slip to 450,000 m^{-2} in Windermere Basin and in the deep central basin. Average biomass was between 10,000 and 100,000 oligochaetes m^{-2} (Figure 11). Q. multisetosus, a pollution-sensitive oligochaete was 42% of the total benthic invertebrate population. L. hoffmeisteri and T. tubifex, pollution-tolerant oligochaetes, were 32 and 10% of the population. Chironomids, of which four genera were reported in 1964, occurred at all of the littoral sites sampled. Mean abundance at the littoral sites was 302 m^{-2}. Visual surveys conducted in 1988 indicate the presence of extensive clam beds in the shallow water between LaSalle Marina and the north east corner of the Harbour.

Although the benthic community in Hamilton Harbour is indicative of a highly eutrophic environment, substantial improvements have occurred in the abundance and community composition since 1964. The "toxic zone" described in 1964 has been reduced from 2 km^2 to a small area at the south end of the Ottawa St. slip. Biomass throughout the Harbour has increased between 5 and 20 fold and the community composition has shifted away from pollution-tolerant species towards more pollution-sensitive species. An additional four genera of chironomids were found in 1984. Sphaerids, which were not found in the 1964 survey, occurred at 11 sites in 1984.

Effect of Sediments on Benthos and Zooplankton

Sediments in the Harbour are contaminated. The levels of contamination are sufficiently high to require that dredgeate be disposed of in confined disposal

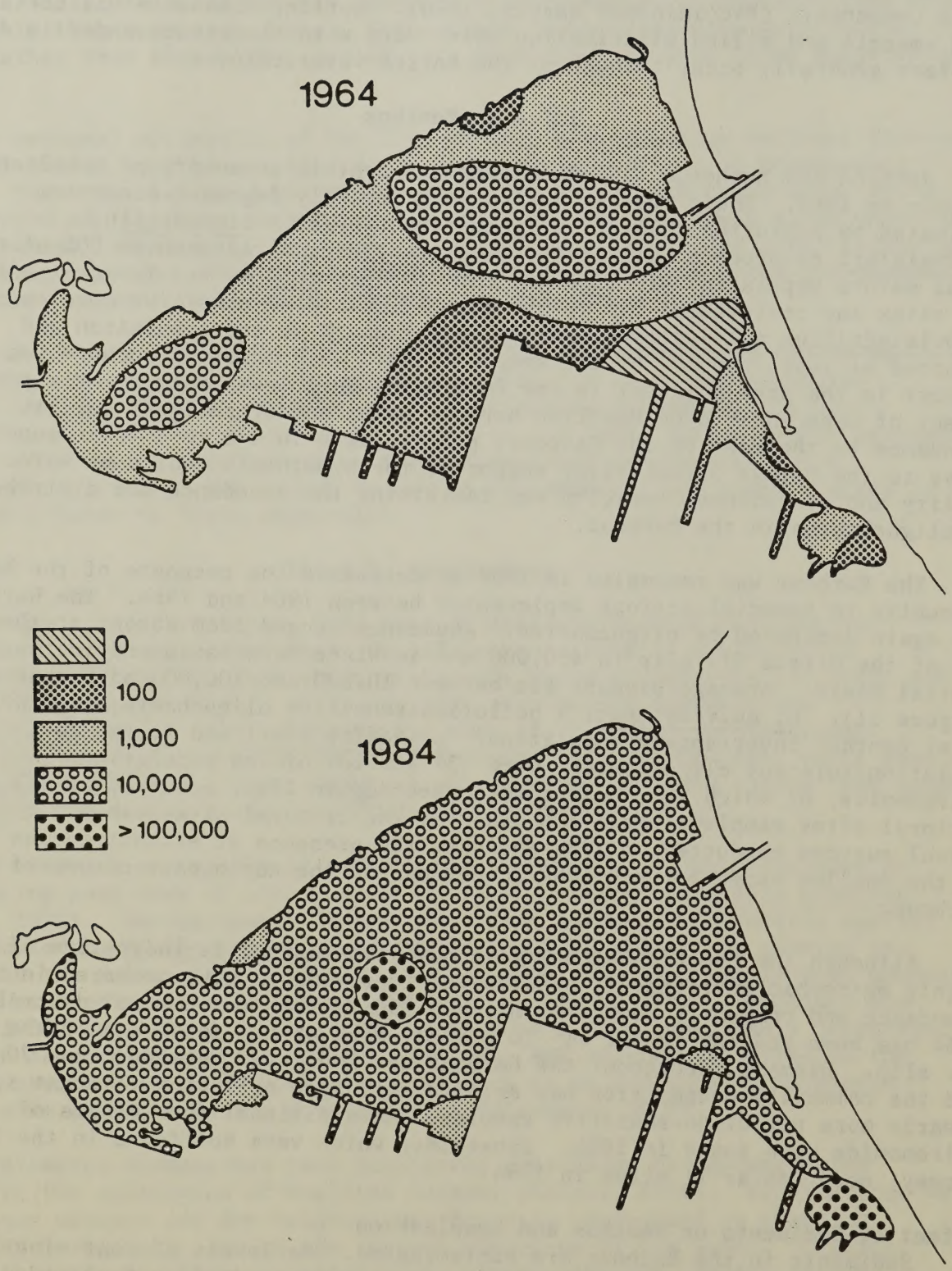


FIGURE 11. ABUNDANCE OF OLIGOCHAETES IN HAMILTON HARBOUR ($NO \cdot m^{-2}$)

facilities, rather than being dumped in the open Harbour or open lake. In other words, if one must move the sediments, certain regulations must be followed.

But do the sediments left in place constitute a hazard? This question has been recently brought to a focus in a protocol for sediment assessment (Water Quality Board, 1988). While the suggestions in the Board's report are largely untested in both a practical and a research sense, agencies involved in the Hamilton Harbour RAP have developed information in line with these protocols.

Elevated concentrations of contaminants in lake sediments are of concern because of potential toxicity or food web related impacts on aquatic biota, particularly benthic invertebrates. Effects on benthic organisms may be acute or chronic, and may lead to an adverse impact on community structure. This may disrupt the species diversity and numbers of predator organisms and ultimately lead to the loss of desirable species at higher trophic levels (e.g. sport fish).

Low hypolimnetic oxygen concentrations in Hamilton Harbour from mid-June to mid-September limits the deep water benthic community to species that can withstand low dissolved oxygen for prolonged periods. Although sediments in the deep water basin are contaminated with organic and inorganic pollutants, the toxicity of these chemicals on benthic invertebrates is masked by the adverse effects of low dissolved oxygen. Attempts to correlate the abundance and composition of the benthic community with contaminant concentrations failed because of auto-correlations between contaminant concentrations, organic composition and grain size of the sediment, depth, and dissolved oxygen (Portt et al. 1989)

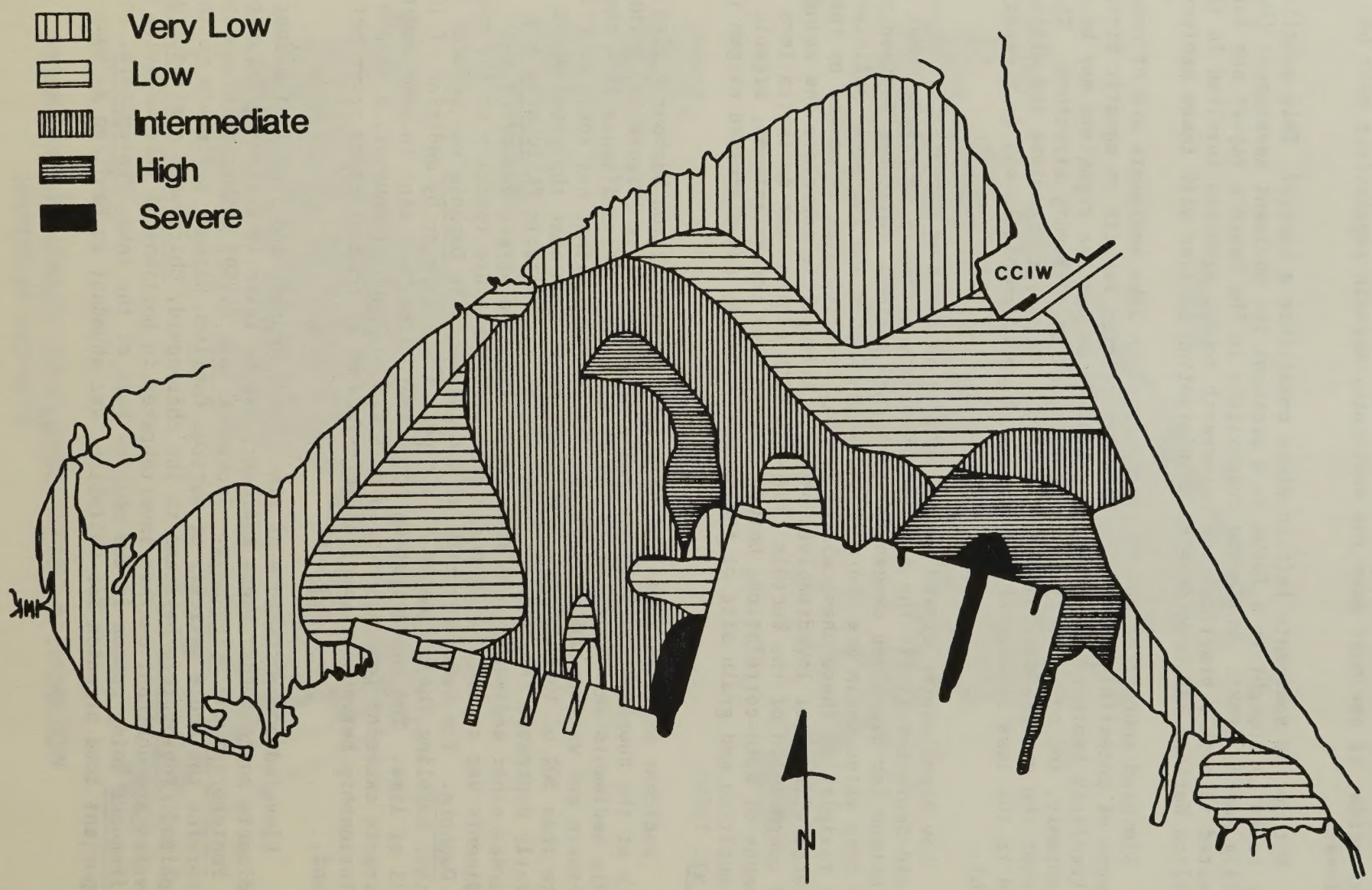
Sediment extracts from 7 of 62 locations in Hamilton Harbour killed 70% or more of the zooplankter, Daphnia magna, within 48 hours (Figure 12). The more toxic sediments were adjacent to the steel mills. The sediments from the northern and western portions of the Harbour were either not toxic or killed less than 30% of the Daphnia. Whole sediments from near the steel mills greatly depressed the oxygen consumption of the bacteria Photobacterium, whereas other sediments were much less toxic. The oxygen demand of the sediments was significantly correlated with the acute toxicity of the sediments to Daphnia. The acute toxicity of the sediments to Daphnia was reduced by either bubbling the sediments with oxygen for 2 days or by addition of 10-200 mg/l of lime. The concentrations of copper, iron, and zinc in some sediment extracts exceeded levels known to be toxic to Daphnia; however, a simple relationship between sediment toxicity and metal concentration could not be found.

Elevated concentrations of zinc, lead, copper, and iron in the deep water sediments suggest that these sediments may be toxic to burrowing organisms such as Pontoporeia and Chironomus. Jackson et al. (1989) conducted bioassays to determine the acute toxicity of various Hamilton Harbour sediments to the amphipod, Pontoporeia hoyi and to the chironomid, Chironomus semireductus. Both species are dominant benthic invertebrates in portions of Lake Ontario, with Chironomus being common in the shallow bays of the lake. Pontoporeia, an important food organism for whitefish, was abundant in Hamilton Harbour in the

Figure No. 12

Acute Toxicity of Hamilton Harbour Sediments

February 1, 1989



late 1800s.

Sediments from the deeper stations in Hamilton Harbour were acutely toxic to Pontoporeia within 168 hours (65-85%). Exposure to sediments from Cootes Paradise, Lake Ontario, the Bay of Quinte, and a shallow water site on the north shore of the Harbour caused less than 15 percent mortality in 168 hours, with no significant difference in mortality among these samples. Cause and effect relationships are difficult to establish from field bioassays. However, concentrations of zinc, lead, iron, and chromium were higher in the toxic sediments (Table 10).

TABLE 10: Mortality of Pontoporeia and Chironomus exposed to sediments from four sites in Hamilton Harbour or three other sites. Also shown are the contaminant concentrations in the sediments from each site. Metals expressed as acid-extracted values, mg/kg unless otherwise stated.

	Location						
	Hamilton Harbour Site				Lake	Bay of	Cootes
	A	B	C	D	Ontario	Quinte	Paradise
Mortality (%):							
Pontoporeia	65	65	85	5	10	15	8
Chironomus	12	25	15	13	8	7	23
Depth (m)	11	23	19	5	125	5	2
Metals:							
Cadmium	3.9	5.2	0.2	2.9	2.0	1.4	1.0
Chromium	62.7	122.6	150.7	30.7	17.6	10.5	10.9
Copper	76.0	101.0	274.6	73.8	68.7	26.7	43.3
Iron[1]	14.2	23.2	25.4	10.7	10.4	10.5	10.3
Manganese[1]	1.5	2.0	2.0	0.6	1.6	0.6	0.7
Nickel	28.7	35.0	0.6	13.9	41.0	16.0	12.7
Lead	181.7	292.3	336.0	56.2	87.0	54.2	69.3
Zinc[1]	1.4	2.0	2.5	0.4	<0.1	0.1	0.25

1: mg/g
Source: Jackson et al., 1989

Hamilton Harbour sediments were not acutely toxic to Chironomus. There was no significant difference in mortality of Chironomus exposed to sediments from a deep water station in Hamilton Harbour and those exposed to sediments from Cootes Paradise. The sublethal effects of Hamilton Harbour sediments on the feeding activity of Chironomus was determined by measuring the percent of gut filled with food. Chironomus exposed to Hamilton Harbour and Cootes sediments showed significantly lower feeding activity (24%) than those exposed to Lake Ontario or the Bay of Quinte sediments (72%).

Results from the acute Pontoporeia bioassay indicate that the deep water

sediments of Hamilton Harbour are unsuitable for colonization by Pontoporeia. Cause and effect relationships are unknown and research is needed to identify the toxic agent(s) and develop remedial actions. Results from the Chironomus bioassay are more difficult to interpret. Low acute toxicity in all Harbour sediments suggests that Chironomus would be successful throughout the Harbour if dissolved oxygen were not limiting. However, reduced feeding activity in the short term assay (192 hours) has implications for growth and long term survival and it is not clear if Chironomus could successfuly colonize the deep water sediments.

Biomagnification of contaminants by benthic organisms may also be of concern due to the potential for transmission to predator species and subsequent accumulation through the food web. Benthic macroinvertebrates (chiefly tubificid oligochaetes) in Windermere Basin and in Lake Ontario near the Ship Canal exhibit tissue concentrations of metals (Cu, Fe, Hg, Zn) and certain organochlorine compounds (PCBs, HCB, DDE, chlordane, heptachlor, aldrin, α-BHC) 2-6 times more than in their associated sediments (MOE, 1987a), which suggests that a transfer from sediments into the aquatic food web is taking place.

Interpreting tissue concentrations in benthic invertebrates and fish is difficult due to our lack of ability to separate the effects of present contaminant loadings to the water from the effects of high contaminant concentrations in the sediment as a result of past loadings. We have no confidence that abatement actions at the sources alone would be effective in reducing the contaminant content of the biota. Hence, remedial measures to deal with the deposits from past loadings may become necessary.

Mobility of contaminants in the sediment due to either physical resuspension of sediment particles, bioturbation, geochemical reactions, or biomagnification is poorly understood in Hamilton Harbour. Only manganese and occasionally iron release from the Harbour sediments has been documented. Biomagnification of contaminants in benthic invertebrates has been observed, but its significance to the warmwater fishery has not yet been estimated.

Sediment trap measurements of suspended sediment fluxes throughout the Harbour in 1987 suggest that resuspension of surficial sediments (and hence recycling of associated contaminants into the water column) appears to be occurring in deep areas of the Harbour as well as those boundary areas most obviously affected by ship traffic and wave action (Charlton pers. comm.). Analysis of organic content and such physical properties as particle size will assist in the interpretation of the processes responsible for resuspension.

While the complete set of tests on Harbour sediments are not yet complete, it is clear that there are problems associated with the contaminants in this material. The scope of the problem can only be partially assessed. That is to say, the degree to which sediments contribute to contaminant issues in the Harbour (such as fish health, bird reproduction, and contaminants in fish fillets) is unknown.

III.4.5 Macrophytes

Cootes Paradise Aquatic Vegetation

The present marsh flora of Cootes Paradise bears little resemblance to that described in pre-20th century writings. The memoirs of Charles Durand (1893), a former Dundas resident, provide some insight into that period's natural history. Durand implies that the marsh in the early 19th century, when he was a boy, was virtually filled throughout its length with emergent aquatic plants. Photographs currently on file at Royal Botanical Gardens (RBG) confirm that as late as 1928 there were, in fact, emergent aquatics growing as far east as the mouth of the Desjardins Canal at the High Level Bridge.

Mr. George North (1910-1983), an amateur naturalist and keen long-time observer of Cootes Paradise, described the marsh flora as it was during the 1920s and early 1930s (pers. comm. to J. Lord of RBG). According to North, the most abundant emergent plant was cattail (Typha sp.) and was associated with many other common wetland species such as burreed (Sparganium spp.) water lily (Nymphaea spp.) and water smartweed (Polygonum punctatum). North noted that manna grass (Glyceria maxima), which is currently the dominant emergent of the marsh, became evident much later. In addition to these emergent species, there were vast amounts of submergent aquatics. Wragg (1949), although he did not cite specific references, also described the marsh circa 1920, "Judging from reports of its condition, 30 years ago it must have been a remarkable place. In addition to the abundant growth of aquatic plants found there today, wild celery (Vallisneria americana) was common and wild rice (Zizania aquatica) so abundant that, in rowing through the marsh, one's boat would be covered with rice. Water was so clean and food so plentiful that ducks remained in thousands until ice formed." Wragg noted that a decline in waterfowl usage, concurrent with a decline in wild rice and wild celery stands, occurred in the ensuing 30 years.

Based on interpretation of historical writings and other sources, permanent reduction of wetland vegetation in Cootes Paradise appears to have begun sometime around the turn of the century and has accelerated rapidly since the 1940s (Table 11). Though documentation is fragmentary, several factors appear to have contributed to this decline. High water events have been correlated with a decrease in abundance and distribution of emergent plant communities in Cootes Paradise (Dept. of Fisheries and Oceans, unpub. data, 1986). However, based on historical descriptions, permanent reductions in marsh vegetation prior to 1900 were not experienced. Historical records from 1840 to the present show that Lake Ontario water levels have undergone wide fluctuations, including extended periods of high water during the 1800s, without permanent damage to the macrophyte communities (Painter et al., 1988). Apparently the emergent vegetation recovered when water levels returned to normal. It would then appear that factors other than water level are involved in the marsh decline.

The wetland vegetation of Cootes Paradise and Hendrie Valley/Carroll's Point area is currently dominated by a small number of hardy emergent species such as manna grass, cattail and giant burreed (Sparganium eurycarpum). There are still small localized stands of bulrush (Scirpus spp.) and sedges (Carex

Table 11: Extent of emergent vegetation in Cootes Paradise.

Year	% of total area
1934	100
1946	41.6
1950	25
1953	12.6
1954	20
1959	40
1962	32
1971	27.9
1972	27
1974	9.3
1980	15
1985	16.9

Source: V. Cairns, DFO, and the Royal Botanical Gardens.

spp.) in the more protected inlets which fringe the basin. The present extent of emergent vegetation is approximately 15% of the total area, and is restricted to areas above the normal high water level.

The open water area of Cootes Paradise measures 250 hectares and is virtually devoid of aquatic plants. Around the edges, submergent communities are dominated by a small number of hardy species, for instance, sago pondweed (Potamogeton pectinatus). In 1946-48, 25 species of submerged aquatic plants were found in Cootes Paradise. In 1968-72 and in 1985, 11 species were observed; and in 1987, only 4 species.

Turbidity caused by algal blooms (in response to high nutrient loading) can cause inhibition of submergent plant growth, ultimately resulting in elimination of plant communities. The Dundas STP has been implicated as the primary source of excessive nutrient loadings to Cootes Paradise since its construction in 1919. It is postulated that the levels of nitrogen and other nutrients, discharged into the marsh, may also have led to the weakening and breaking of stems of some species of emergent macrophytes growing on floating root and rhizome mats (Boar and Crook, 1985). This mechanism can cause widespread loss of macrophyte stands. The extent of the marsh that was floating and therefore possibly affected by high nitrogen loading is unknown.

Turbidity derived from suspended sediments (erosion from urban storm water drainage) reduced light penetration to 14-38 cm throughout the summer of 1985 (Portt et al., 1986). Silt may also coat leaves, further inhibiting photosynthesis, and may physically damage stems and leaves. High silt loadings can also change substrate texture rendering it unsuitable for some plant species to colonize. Siltation in Cootes Paradise has changed bottom contours dramatically, resulting in a shallower basin particularly in the eastern portion (Painter et al., 1988). This shallowness has fostered wind-generated

resuspension of bottom sediments and therefore has compounded the light penetration problems created by phytoplankton blooms.

A major role in the decline of the Cootes Paradise macrophyte communities must also be attributed to the spawning and feeding activities of carp (Cyprinus carpio) in the marsh. Carp were implicated by Wragg (1949) as responsible, in part, for the eradication of wild rice and wild celery from Cootes Paradise 30 years before he undertook his studies. Although he did not cite references, Wragg suggested that the apparent failure to re-establish these two plants, circa 1937, was again due to the destructiveness of carp. An ambitious programme of carp control was conducted by the Royal Botanical Gardens in 1952 and again in 1954-56. The latter effort removed 130,000 adult carp and resulted in dramatic improvement in the distribution and abundance of aquatic vegetation in the marsh (Lamoureux, 1961). However, the programme was discontinued and has not been repeated since that time.

There are a number of other minor factors which may have contributed to the decline of macrophyte communities in Cootes Paradise. For example, damage to replanted wild rice stands in 1951-56 was caused by larvae of an unidentified species of moth (Lamoureux, 1957). In addition, grazing by muskrats may have had some local effects, but whether permanent damage occurred is unknown.

It would appear that the major factors currently limiting recovery of the macrophyte communities in Cootes Paradise are turbidity, high water and carp. If marsh restoration is to be achieved, practical methods of controlling these factors must be sought.

Hamilton Harbour Aquatic Vegetation

The composition and abundance of warmwater fisheries in Hamilton Harbour is influenced by the type, density, and distribution of submerged and emergent aquatic plants. Apart from an obvious role in sediment stabilization, aquatic vegetation provides essential fish habitat. Submerged macrophyte cover influences phytoplankton and zooplankton populations, increases epiphytes and littoral invertebrates, and provides spawning, nursery, and adult habitats for largemouth bass, pike, bowfin, sunfish, longnose gar, and crappies. Fisheries production in the littoral zone appears to be optimum at intermediate plant densities. Sparsely vegetated areas offer little protection from predators while extremely dense vegetation impedes larger predators and reduces feeding success. Plant abundance is influenced by light, water levels, nutrients, substrate characteristics, ice scour, and lake morphometry (Duarte et al., 1986).

Emergent vegetation provides spawning habitat for largemouth bass and northern pike. Pike prefer flooded sedges (Carex sp.), grasses (Spartina, Phalaris) and water plantain (Alisma). They will also spawn on flooded mats of broken cattails (Typha).

There are no data quantifying the extent of emergent marsh vegetation in Hamilton Harbour prior to 1900. Kerr and Kerr (1860 - 1898) reported that marshes extended along the entire south shore of the Harbour, in the north east corner (Brant's Pond), and in the mouth and lower reaches of Grindstone Creek.

The entire 49.6 km south shore (from Desjardins Canal to the Burlington Canal) was restructured between 1900 and 1985 (Fig. 1) resulting in a loss of 85 percent of the original vegetated shoreline. Whillans (1979) concluded that the loss of the south shore marsh was a major factor contributing to the decline of the warmwater fishery.

The emergent marsh in Grindstone creek declined from 37.8 ha in 1934 to 5.1 ha in 1985 (Table 12). Most of the loss (23 ha) occurred in the area of the Valley Inn Road. Possible factors responsible for marsh loss include ice scour, damage by carp, siltation, reduced light penetration, and increased water levels. Recent analysis of marsh losses since 1934 show a good correlation with elevated water levels (V. Cairns, DFO, pers. comm.).

The Grindstone Creek marsh is the last remaining stand of emergent vegetation in Hamilton Harbour and the only site suitable for pike reproduction. Eighteen adult pike were observed in the vicinity of the boardwalk marsh in 1985. Only 1 pair were spawning. There was no evidence of pike spawning in Cootes Paradise in 1985 or 1987.

TABLE 12: Area (ha) of emergent vegetation in the Grindstone Creek marsh from 1934 - 1985.

	Area (ha.)			
Year	Valley Inn	Sunfish Pond	Lower Marsh	Boardwalk Marsh
1934	23.0	2.6	6.9	5.3
1939	3.5	2.6	7.9	5.7
1950	1.1	0.1	2.4	3.5
1954	3.0	0.5	1.2	4.2
1959	1.1	2.3	4.9	4.2
1961	0.7	0.9	3.5	5.0
1969	0.6	0.5	1.9	3.8
1972	10.2	0.6	3.4	3.6
1974	0	0.2	0	1.4
1980	0.4	0.4	1.4	3.5
1985	0.4	0.3	0.7	3.7

There is insufficient spawning habitat (emergent marsh) in Hamilton Harbour to support a viable pike fishery (20-25 kg/ha). The ratio of spawning habitat to adult habitat is 0.06 in Hamilton Harbour (using 1987 data of 5 ha of suitable spawning habitat in Grindstone Creek and 64 ha of vegetated adult habitat in the Harbour). This is considerably less than the 0.3-0.4 ratio of spawning habitat to adult habitat recommended for productive marshes (Inskip, 1982). Based on these calculations, an additional 19-26 ha of suitable spawning habitat are required to sustain 64 ha of adult pike habitat.

The distribution and relative abundance of submerged vegetation was determined during 1987 from echosounding along the 1.3 m contour of the Harbour. Twenty-two transects perpendicular to shore were used to establish

the maximum depth of macrophyte growth. Plants were rarely found at depths greater than 2 m. Hence, the extent of littoral zone colonized by submerged plants was determined by measuring the area between the shore and the 2m contour. However, plants rarely grew at depths less than 0.5 m. Therefore, the above method slightly overestimated the area of distribution of aquatic vegetation in the Harbour. Echolocating was used initially to identify areas of dense, heavy, moderate, and sparse vegetation. Species richness and density (number of plants/m^2) in these sites were subsequently measured by direct observation (SCUBA) at three locations in each vegetation type (V. Cairns, DFO, pers. comm.).

There are 199 ha of littoral habitat (less than 2 m deep) remaining in Hamilton Harbour. Only 45 percent of the total littoral area contained moderate to dense vegetation. Plant abundance in the remaining 55 percent of the littoral zone ranged from absent to sparse (3 plants/m^2) . Submerged vegetation was confined to the north shore and to the west shore of the Harbour between the former Lax property and the Desjardins Canal (Figure 13). Plants did not grow at depths greater than 2.5 m, probably due to poor light penetration below that depth. Plants were absent along the south shore east of the Royal Hamilton Yacht club. The littoral zone along the east shore of the Harbour is shallow enough to permit vegetation but plant growth is limited by almost constant wave action and poor light penetration. Prior to 1985, the east shore, south of the Burlington Canal, was moderately vegetated (V. Cairns, DFO, unpub. data). Shoreline restructuring to accommodate the West Service Road transformed this area into a high energy rubble shore that reflects wave action and inhibits plant growth.

With the exception of a small area (16 ha) of dense vegetation in the sheltered LaSalle marina, the majority of the north shore was moderately vegetated. Plant densities in areas of dense, moderate, and sparse vegetation were 400, 63, and 3 plants/m^2, respectively. Dense and sparse areas were represented by single species (Myriophyllum and Vallisneria, respectively). Maximum species richness in Hamilton Harbour occurred in moderately vegetated areas and was limited to only five species (Elodea canadensis, Vallisneria americana, Heteranthera dubia, Myriophyllum spicatum, and Potamogeton pectinatus). These plants are characteristic of eutrophic environments (Crowder and Bristow, 1986).

Crowder and Bristow (1986) reported that reduced light transparency was the most important factor limiting the distribution, abundance, and diversity of submerged aquatic plants in the Bay of Quinte. Secchi disk readings averaged 1.2 m in the Bay of Quinte and submerged vegetation did not grow at depths greater than 2 m (Crowder and Bristow, 1986). These data are consistent with the 2 m maximum depth of plant colonization for this Secchi depth predicted by Chambers and Kalff (1985). Similar relationships between light penetration and plant distribution appear to be occurring in Hamilton Harbour. In areas exposed to wave actions, it is likely that the clarity of water will decrease in the shore zone less than 2 m deep.

Lower Secchi readings close to shore indicate that nearshore conditions such as suspended sediments may be limiting light penetration at depths less than 2 m. Secchi depth increased within the protected confines of the LaSalle

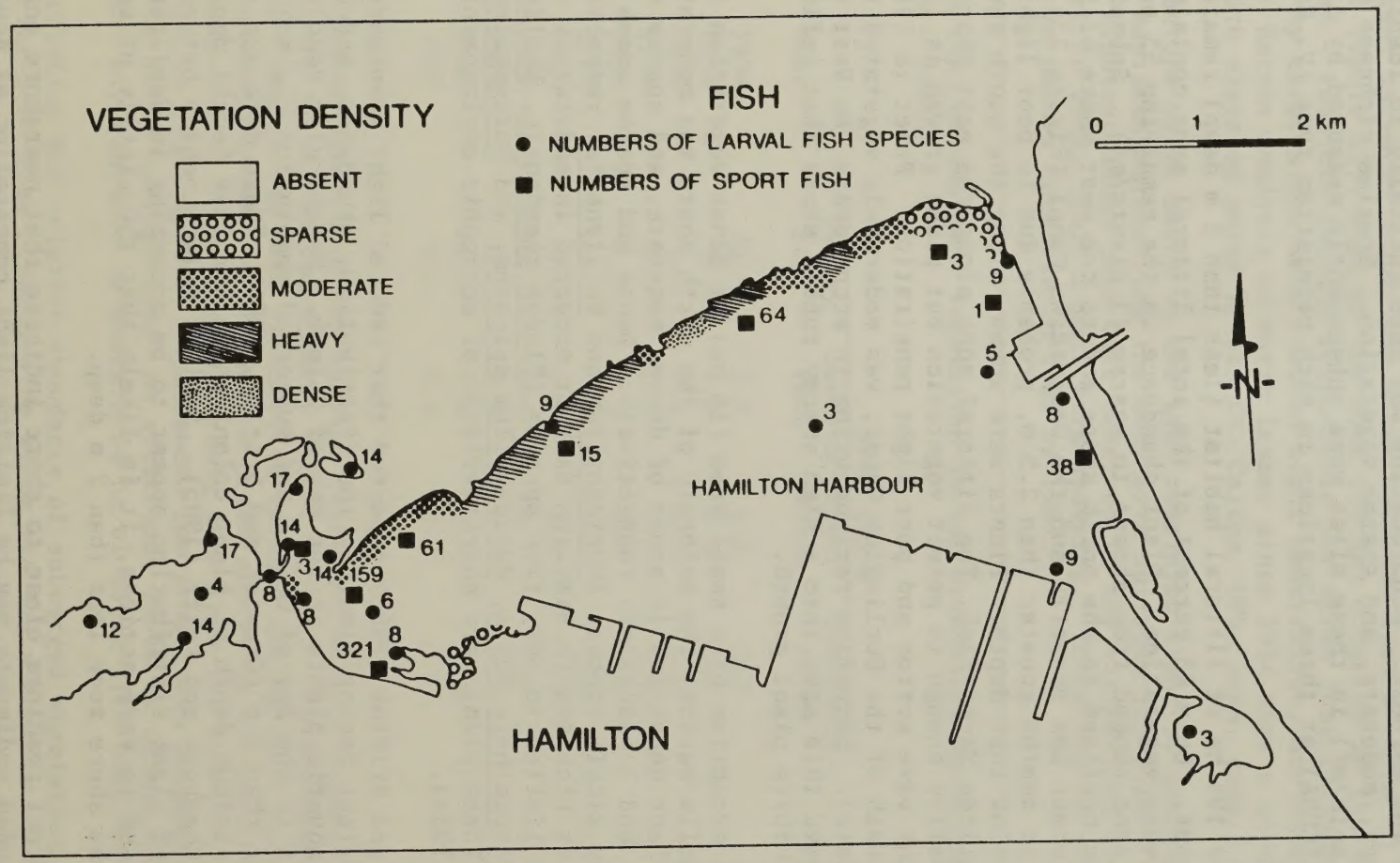


FIGURE 13. VEGETATION DENSITY AND FISH DISTRIBUTION IN HAMILTON HARBOUR

Marina suggesting that the presence of docks and wave barriers reduced these nearshore factors. Not surprisingly, the sheltered area near the marina was also the only habitat in the Harbour characterized by dense vegetation (400 plants/m^2). The increased abundance of plants further dampened the effects of wave action and stabilized bottom sediments. Unprotected littoral habitat on both sides of the sheltered marina had moderate to heavy vegetation (Figure 13).

The source and fate of suspended sediments in Hamilton Harbour are not fully understood. Grindstone Creek, Indian Creek, Cootes Paradise, the STPs, combined sewer overflows, and erosion are obvious sources of suspended sediments to the Harbour. In addition, resuspension of existing sediments in the nearshore zone by wave action and possibly by the foraging action of carp also contributes suspended solids to the water column. Unfortunately there are insufficient suspended sediment data in the littoral zone of Hamilton Harbour to determine: 1) if suspended sediments are responsible for decreased light penetration close to shore; and 2) the relative importance of sediment inputs versus resuspension as factors limiting light penetration.

Breakwalls have been constructed along more than 5 km of the north shore leaving the area between Carroll's Point and Willow Point as the largest stretch of unprotected shoreline. The clay banks at this site show signs of recent extensive erosion by wave action confirming its role as a source of sediments to the Harbour. Although erosion along the north shore is minimized by the breakwalls, the restructured concrete shore reflects wave energy back into the littoral zone and increases sediment resuspension. The combination of reduced light penetration and unstable substrate limits plant abundance and distribution. It also reduces the diversity and abundance of benthic invertebrates and fish.

Light penetration is severely limited at the mouth of Grindstone Creek. Secchi depths at this site ranged from 14 to 38 cm throughout the summer of 1985 (Portt, 1986). Suspended sediments frequently exceed 80 mg/l (MOE, 1986b) and appear to be the most important factor limiting light penetration. Suspended clay and silt transported by Grindstone Creek during erosion events is deposited in Sunfish Pond and in the Valley Inn road area. The mean depth at both sites is now less than 0.5 and 1 m, respectively. The creek, Sunfish Pond, and the estuary are turbid during periods of runoff. However, Grindstone Creek is clear during dry periods but Sunfish Pond and the estuary remain turbid, suggesting that wind (and/or carp) are responsible for sediment resuspension.

III.4.6 Fish

Trends in the Hamilton Harbour Fishery

Historically, Hamilton Harbour was one of the most diverse and important fish habitats in western Lake Ontario, supporting a coldwater fishery dominated by lake trout, whitefish, and lake herring. Prior to 1800, the fishery also included Atlantic salmon and lake sturgeon. Kerr and Kerr (1860-1898) reported seasonal feeding migrations of lake trout and whitefish into Hamilton Harbour in June and July. Summer feeding migrations were followed by spawning runs in October and November as millions of whitefish and lake herring entered the

Harbour to spawn on gravel shoals along the north and west shores (Holmes and Whillans, 1984). The commercial catch of lake herring in the late 1800s represented 48 percent of the western lake fishery and made up 15 percent of Lake Ontario's total commercial catch.

Cootes Paradise and the south and west shores of Hamilton Harbour consisted of shallow water marshes that provided spawning, nursery, and adult habitats for the warmwater fish community. Pike and bass were the dominant recreational and commercial warmwater species. Approximately 12,270 kg of pike were taken by the commercial fishery in 1871 and bass fishing peaked in 1879 with a record catch of 5,400 kg (Holmes and Whillans, 1984). These catches do not include the large sport fishery (primarily spearing) for pike and bass in the north western end of the Harbour near Carroll's Point. Whillans (1977, cited in Holmes and Whillans, 1984) estimated the annual mortality from spearfishing at 18,000 kg/year. The diverse warm water fishery included pike, bass, yellow perch, sunfish, muskellunge, walleye, drum, burbot, channel catfish, brown bullhead, and white sucker.

Decline of the Fishery: By 1900, the coldwater fishery was responding to deteriorating water quality, competition from invading species (smelt), overfishing, and habitat loss associated with urban and industrial development. The first collecting sewer for the city of Hamilton was completed in 1854 (Threader et al., 1989). Prior to this, sewage disposal from water closets emptied directly into Cootes Paradise and Hamilton Harbour and the combined effects of eutrophication, agricultural expansion, and industrial development were reflected by the Harbour fisheries. Commercial catches of lake trout, whitefish, and herring peaked at 4,500, 13,600 and an impressive 114,000 kg per year, respectively, in the late 1800s. By 1950, annual catches of lake trout, whitefish and herring had dwindled to 0, 181, and 68 kg, respectively.

Stresses Affecting the Coldwater Fishery: The coldwater fishery in Hamilton Harbour responded to a number of stresses including overfishing, competition from newly introduced species, and deteriorating water quality. Seining at the canal during feeding and spawning migrations, combined with heavy gill net fishing, substantially reduced lake trout, whitefish, and herring populations (Whillans, 1979). In addition, cold water species were unsuccessfully competing with smelt for benthic invertebrates (Pontoporeia and sphaerids). Smelt were first reported in Hamilton Harbour in 1865 (Whillans, 1979) and were thought to be an important factor contributing to the decline of whitefish populations in the eastern basin of Lake Ontario (Christie, 1973).

There are few historical references describing the effects of eutrophication and toxic chemicals on the coldwater fishery. Whillans (1979) cites references from Kerr and Kerr, the Fisheries overseers from 1860-1898, describing deteriorating water quality on lake sturgeon spawning beds along the south shore and other instances of dead fish in close proximity to industrial discharges. Although warmwater fisheries declined after the installation of the first collecting sewer in 1854, there were no data describing the effects of eutrophication on the hypolimnetic waters of the Harbour. Excessive nutrient inputs to the Harbour encourage algal production. The decaying algae and oxygen demanding sediments combine to deplete the dissolved oxygen in the hypolimnion during the summer months, effectively eliminating the deep water

habitat necessary to sustain the coldwater fishery. Analyses of sediment core samples are underway to determine when this cycle of anoxia began in the Harbour and if this period of reduced oxygen coincided with the loss of benthic invertebrates and coldwater fisheries.

Stresses Affecting the Warmwater Fishery: The collapse of the coldwater fishery was quickly followed by a rapid decline in the number of warmwater fish and a transition from a predator-dominated fishery to one dominated by forage species. Overfishing, toxic discharges, introductions of exotic species (carp, alewife, and white perch) and habitat loss were the major factors responsible for reductions in the warmwater fishery. These changes paralleled the growth of Hamilton as an industrial and urban centre. The city's population increased from 3,000 in 1840 to 25,000 by 1857 and reached 155,000 in 1931 (Threader et al., 1989). Population increases were accompanied by rapid industrial expansion along the south shore of the Harbour. By 1880, Hamilton was already established as a major iron manufacturing centre and in 1910, the steel producers merged to become the Steel Company of Canada. International Harvester expanded in 1911 and Dofasco, the second steel mill to be built on the south shore of Hamilton Harbour, was established in 1912. The Harbour was now receiving effluents from three municipalities, two of Canada's largest steel producers, and textile, rubber, paint, and solvent manufacturers. The Fisheries Overseer reported many occurrences of dead and dying fish along the vegetated shoreline (Whillans, 1979).

The war years from 1915 to 1918 were accompanied by escalating steel and munitions production in Hamilton. Expanding industries required more land on the south shore and many of the shallow water marshes were filled to provide roads, docks, and factories. This trend continued in the post-war years and by 1959, approximately 22 percent of the open water area in the Harbour had been lost to landfilling (Threader et al., 1989). Although land reclamation along the south shore significantly reduced the open water area (and the retention time of the basin), the most significant impact was the loss of the shallow water marsh habitats that supported the warmwater fish community. Prior to industrial development, the 43 km south shore was a complex marsh ecosystem colonized by emergent and submerged vegetation. The irregular shore line had many inlets that in some cases created long bays extending more than 1 km inland. Landfilling reduced the total littoral shoreline from 65 km in 1800 to 20 km by 1985 (Figure 1). Most of the south shore has been dredged to at least 8 m deep. The landfilled shore is separated from the Harbour by steeply sloped berms or by vertical pilings. There is no suitable fish habitat along the south shore of Hamilton Harbour east of the former Lax property.

The loss of marsh habitat significantly reduced the abundance and distribution of warmwater fish. Disappearing wetlands along the south shore restricted the fishery to the north and west shores of the Harbour and to Cootes Paradise.

Present State of Hamilton Harbour Fishery

Larval Fish: Larval and juvenile fish surveys were conducted in 1985 and 1987 by the Department of Fisheries and Oceans in littoral and open water areas of both Hamilton Harbour and Cootes Paradise. The most common larval fish are listed in Table 13 of the 42 species of larval fish identified (Table 14). Most species were caught in the west end of the Harbour and in Cootes Paradise (Figure 13).

Twenty-seven adult Northern Pike were observed in Grindstone Creek. Spawning was observed and pre and post spawning females and males were confirmed. Larval pike were not collected but this is normal since larval pike are particularly difficult to collect.

TABLE 13: Larval fish composition, 1985 and 1987.

Species	Percent Composition
Gizzard shad	50%
Alewife	32%
Yellow perch	5.1%
Bluegill	2.8%
Pumpkinseed	2.5%
White perch	2.3%
Total	95%

Adult Fish: Hamilton Harbour supports a diverse fishery represented by 19 families, 42 genera, and 59 species (Table 14). Although diversity is high, community structure has shifted from the larger, long-lived species common in the late 1800s to smaller, short-lived species characteristic of eutrophic environments.

The Hamilton Harbour and Cootes Paradise fishery consists of two distinct species groups. The first group, represented by crappies, sunfish, gizzard shad, and brown bullheads, remain in the Harbour and marsh throughout the year. They tend to congregate in Cootes Paradise in the spring and move into the western end of Hamilton Harbour in the fall.

The second major group, represented by smelt, white sucker, yellow perch, brown trout, spottail shiners, herring, lake chubs, and Pacific salmon, migrate into Hamilton Harbour from Lake Ontario to feed and/or spawn. Abundance is highest in the spring and fall (Table 15) although small numbers of migrating species were found in the summer at the eastern end of the Harbour close to the Burlington Canal.

The relative abundance (catch per unit effort) and distribution of fish in Hamilton Harbour were determined from gillnetting surveys conducted from September to December, 1984 and from April to September, 1985 (Portt, 1988). Additional data were obtained from an electrofishing survey of the Harbour by the OMNR in October, 1987.

TABLE 14: Fish species in Hamilton Harbour and Cootes Paradise, 1984-87.

Scientific Name	Common name	Larvae
Petromyzon marinus	sea lamprey	
Anguilla rostrata	American eel	
Lepisosteus osseus	longnose gar	
Amia calva	bowfin	
Alosa pseudoharengus	alewife	*
Dorosoma cepedianum	gizzard shad	*
Oncorhynchus kisutch	coho salmon	*
Oncorhynchus tshawytscha	chinook salmon	*
Salmo gairdneri	rainbow trout	
Salmo trutta	brown trout	
Salvelinus namaycush	lake trout	
Coregonus artedii	lake herring	
Couesius plumbeus	lake chub	
Osmerus mordax	American smelt	*
Umbra limi	central mudminnow	*
Esox lucius	northern pike	
Carassius auratus	goldfish	*
Cyprinus carpio	carp	*
Notemigonus crysoleucas	golden shiner	*
Notropis atherinoides	emerald shiner	*
Notropis hudsonius	spottail shiner	*
Notropis heterolepis	blacknose shiner	*
Notropis heterodon	blackchin shiner	
Notropis cornutus	common shiner	*
Notropis chrysocephalus	striped shiner	*
Notropis volucellus	mimic shiner	*
Pimephales promelas	fathead minnow	*
Pimephales notatus	bluntnose minnow	*
Semotilus atromaculatus	creek chub	*
Rhinichthys atratulus	blacknose dace	*
Carpiodes cyprinus	quillback	
Catostomus commersoni	white sucker	*
Catostomus catostomus	longnose sucker	
Hypentelium nigricans	northern hog sucker	
Ictiobus cyprinellus	bigmouth buffalo	
Ictalurus nebulosus	brown bullhead	*
Ictalurus punctatus	channel catfish	*
Ictalurus melas	black bullhead	*
Ictalurus natalis	yellow bullhead	*
Noturus gyrinus	tadpole madtom	*
Fundulus diaphanus	banded killifish	*
Labidesthes sicculus	brook silversides	*
Culaea inconstans	fivespine stickleback	*
Percopsis omiscomaycus	trout perch	*
Morone americana	white perch	*
Morone chrysops	white bass	*
Ambloplites rupestris	rock bass	*
Lepomis gibbosus	pumpkinseed	*
Lepomis macrochirus	bluegill	*
Micropterus dolomieui	smallmouth bass	*
Micropterus salmoides	largemouth bass	*
Poxomis nigromaculatus	black crappie	*
Poxomis annularis	white crappie	
Percina caprodes	logperch	*
Etheostoma nigrum	johnny darter	*
Etheostoma caeruleum	rainbow darter	*
Perca flavescens	yellow perch	*
Stizostedion vitreum	walleye	
Aplodinotus grunniens	freshwater drum	*

TABLE 15: Seasonal changes in the numbers of fish caught in index gillnets in Hamilton Harbour from September 1984 to August 1985, and Cootes Paradise from April to August 1985.

	1984				1985				
Species	Sept.	Oct.	Nov.	Dec.	Apr.	May	June	July	Aug.
Hamilton Harbour									
White perch	284	293	414	25	227	447	356	556	513
Alewife	441	101	19	5	72	1285	3445	832	499
Carp	19	40	58	9	3	7	20	23	27
White sucker	15	29	28	37	67	73	33	33	20
Yellow perch	39	93	38	12	219	445	141	3	33
Brown bullhead	69	158	80	30	151	255	88	80	48
Brown trout	3	7	15	14	28	28	2	5	1
Cootes Paradise									
White perch					1158	929	911	608	1038
Alewife					5	297	3273	3350	184
Carp					82	76	53	86	64
White sucker					45	19	0	0	0
Yellow perch					80	10	4	2	10
Brown bullhead					271	169	78	67	98
Brown trout					3	1	2	0	2

The 1985 fish community in Hamilton Harbour and Cootes Paradise was dominated by warmwater planktivorous, herbivorous, and benthivorous species (Table 16). Alewife, white perch, and gizzard shad represented 92 percent of the total catch in Cootes Paradise (52, 32, and 8 percent respectively) and 71 percent of the Hamilton Harbour catch (56, 15, and 1 percent, respectively).

Differences in species composition reflected the presence of species that migrate between Lake Ontario and Hamilton Harbour and fewer carp and gizzard shad in the Harbour. Large piscivores such as pike, garpike, largemouth and smallmouth bass, channel catfish, and bowfin were rare. The total number of fish captured in Hamilton Harbour and Cootes Paradise was similar although Hamilton Harbour received 30 percent more fishing effort.

Total fish biomass (kg. of fish captured between April and September, 1985) in Cootes Paradise was 1.5 times greater than the biomass in Hamilton Harbour (Table 16). Ninety-four percent of the fish biomass in Cootes Paradise was contributed by carp, gizzard shad, white perch, alewife, and brown bullhead. These species contributed only 60 percent of the total biomass in Hamilton Harbour. Apart from fewer gizzard shad and carp in the Harbour, the most significant difference between the two sites was the contribution of other species to the total biomass. Thirty-two percent of the Hamilton Harbour biomass represented Lake Ontario species migrating into the Harbour. The largest contributors included white suckers, yellow perch, brown trout, spottail shiners, and American smelt (10, 9.2, 7.3, 3.6, and 2.4 percent of the

TABLE 16: Total gillnet[1] catch, and biomass of fish in gillnet catch, in Hamilton Harbour and Cootes Paradise, April to September, 1985; and electrofish catch in Hamilton Harbour, October, 1987.

	1985				1987
	Hamilton Harbour		Cootes Paradise		Ham. Harb.
Species	Catch[2]	Biomass[3]	Catch[2]	Biomass[3]	Catch[2]
Alewife	9075	275.0	8612	266.2	37
White perch	2449	298.3	5264	491.3	337
American smelt	1718	36.1	0	0	0
Spottail shiner	841	42.1	97	1.4	7
Yellow perch	746	138.3	124	10.2	75
Brown bullhead	458	53.9	725	94.4	666
White sucker	308	151.0	66	40.6	44
Gizzard shad	180	74.7	1309	554.5	36
Carp	99	262.1	370	758.3	27
Brown trout	78	108.6	9	16.8	13
Trout perch	45	0.6	17	0.2	0
Pumpkinseed	29	1.3	46	1.5	622
White bass	14	6.0	3	1.0	0
Freshwater drum	11	11.2	12	17.1	1
Carp X Goldfish	10	10.2	9	11.5	0
Rock bass	6	0.7	1	0.2	15
Lake trout	5	10.6	0	0	0
Channel catfish	4	1.3	10	8.9	1
Black crappie	3	0.6	9	1.7	2
Rainbow trout	2	0.4	5	6.9	2
Goldfish	2	1.2	17	7.3	5
Northern pike	2	7.4	3	2.1	0
Smallmouth bass	2	0.5	0	0	2
Lake chub	1	0.1	0	0	0
Lake herring	1	0.1	0	0	0
Longnose gar	0	0	1	0.8	0
Chinook salmon	0	0	0	0	10
Largemouth bass	0	0	0	0	71
Bowfin	0	0	1	2.1	0
Emerald shiner	0	0	0	0	7
Brook silversides	0	0	0	0	5
Golden shiner	0	0	0	0	4
Bluntnose minnow	0	0	0	0	2
Total Number of Fish:	16091		16710		2005
Total Number of Species:	27		22		27

1. Experimental gillnets (64m long X 2m deep) consisted of 8m long panels of 2.5, 3.8, 5.1, 6.4, 7.6, 10.2, 12.7, and 15.2 cm stretch mesh. They were set six times from April to September, 1985, at six locations in Hamilton Harbour and four in Cootes Paradise.
2. Numbers of fish.
3. Kilograms of fish.

total biomass respectively). The remaining 21 species contributed only 2.5 percent of the fish biomass in the Harbour (Table 16).

The Ontario Ministry of Natural Resources conducted an electrofishing survey in October, 1987 to determine the abundance and distribution of sportfish in Hamilton Harbour. Fishing was confined to the littoral zone (1.3 m deep). Fish density (no. of fish per m^3) was determined from four 100 meter runs in each habitat type (Table 16). Habitats were defined by the density of vegetation ranging from absent to dense. Acoustic surveys conducted in 1984 and 1985 indicate that fish were rarely found (densities never exceeded 0.1 fish/m^3) at depths greater than 10 m during the summer months. Fish abundance in the deeper water increased in December, possibly a response to improved oxygen conditions.

Specific Concerns about Contaminant Levels in Fish

Until 1985, sport fish collected from Hamilton Harbour for contaminant analysis had usually been limited in numbers of specimens of any single species caught. In 1985, large collections were obtained, and analyses have been completed for most of the parameters specified. Review of these results enabled the consumption advice contained in the annual Guide to Eating Ontario Sport Fish to be upgraded (MOE, 1988a).

Five of the twelve species listed in the Guide have limitations on consumption of some sizes of those fish. One species is advised for restricted consumption of all sizes sampled, and seven species have no advised consumption limitations.

Consumption limitations arise from the presence of one or more of three contaminants: mercury, PCBs, and Mirex. Mercury levels in the edible portion of freshwater drum (sheepshead) were found to average 0.56 mg/kg (range 0.16 to 1.2). Statistical projection indicates that this species would exceed 0.5 mg/kg mercury in the 35 to 45 cm size range, and 1.0 mg/kg mercury in the 45 to 55 cm size range. Assessment of the organic contaminant data for this species showed Mirex levels exceeded the 0.1 mg/kg Federal guideline in the 45 to 55 cm size range of fish in this sample, resulting in further advised restrictions on the consumption of large freshwater drum.

In white perch, both PCB and Mirex were found to exceed the respective Federal guidelines of 2.0 mg/kg PCB and 0.1 mg/kg Mirex in the 25 to 30 cm length range. Mercury was calculated to exceed the 0.5 mg/kg guideline in the 30 to 35 cm size range, however this exceedence is over-ridden by the exceedences for PCB and Mirex.

Carp over 65 cm in length are advised for restricted consumption based on the projection that PCBs will exceed 2.0 mg/kg in specimens of this size.

While the sample of channel catfish was small, the PCB and Mirex levels in nearly all individuals exceeded the Federal guidelines. For this reason, all sizes of channel catfish from Hamilton Harbour are advised for restricted consumption only. This includes specimens in the length range from 20 to 65 cm.

Few brown trout were collected, and most of them exceeded the Federal guideline for Mirex. Calculations indicated that brown trout from 45 to 65 cm would exceed 0.1 mg/kg Mirex. Brown trout in the size range collected were calculated not to exceed the 2.0 mg/kg PCB or 0.5 mg/kg mercury guidelines.

The other seven species (rainbow smelt, brown bullhead, northern pike, black crappie, white sucker, yellow perch, and white bass) are considered suitable for consumption in regard to Federal guidelines for mercury, PCB, Mirex and DDT.

More recent data were collected in 1987 by Fisheries and Oceans. Composite whole fish samples of carp, white perch, brown bullheads, and white suckers (two pooled samples of 10 large and 10 small fish of each species) were analyzed in 1987. The results indicate that carp and white perch in Hamilton Harbour are accumulating PCBs. Concentrations of Mirex, DDT, DDE, HCB, Chlordane, Dieldrin, and Endrin were below consumption advisory levels. PCB accumulation in carp occurs at several other sites on Lake Ontario and consumption advisories (based on PCB's, Mirex and pesticides) are in effect at five of the nine sites sampled in Lake Ontario and the St. Lawrence River (MOE, 1988a).

While fish from Hamilton Harbour have accumulated trace organics, the levels in edible portions (muscle) have declined steadily between 1972 and 1981. Table 17 illustrates the earliest record and the 1981 record for PCB concentrations in Hamilton Harbour fish. Major reductions in the PCB content have occurred.

TABLE 17: PCB concentrations in fish from Hamilton Harbour, in mg/kg wet weight. Consumption guide is 2 mg/kg.

	Earliest record		1981
Fish	Year	Concentration	Concentration
Pike		-	0.49
Carp	1976	8.9	0.02
Bullhead	1972	4.0	0.04
Yellow Perch	1976	0.52	0.1
White Perch	1978	1.13	0.42
Sunfish	1972	2.5	0.02

The source of contaminants accumulating in Hamilton Harbour fish is complicated by seasonal movements between the Harbour and the lake. At least 15 species, including Pacific salmon, lake trout, rainbow trout, brown trout, white perch, white suckers, yellow perch, American smelt, white bass, freshwater drum and carp, migrate into the Harbour and Cootes Paradise from Lake Ontario. Some species, such as carp and white perch, remain in the Harbour (and Cootes) from May-November and contaminant burdens during this period of maximum feeding are strongly influenced by local conditions. Trout and salmon enter the Harbour for short periods in the spring and fall and

contaminant burdens in these species are more representative of Lake Ontario exposure. Consumption advisories for salmon and trout are in effect at most sites on Lake Ontario.

Studies of blood lead levels have demonstrated little difference between Hamilton Harbour fish and those from other parts of the Great Lakes. In fact, fish from Toronto Harbour and other Lake Ontario locations were more contaminated. This was true even for benthic feeding species which generally accumulate more lead than pelagic feeders.

Tissue levels of PCBs and other organochlorines in white suckers from Hamilton Harbour were similar to levels in suckers from several sites along the north shore of Lake Ontario (Table 18). These data suggest that contaminants in Hamilton Harbour fish, particularly non-resident species, are strongly influenced by Lake Ontario. Tissue burdens in non-migratory Harbour predators such as pike and bass are also affected by Lake Ontario contaminants. Migrating alewife, smelt, white perch, and yellow perch, are important food for resident fish. Hurley (1986) reported that these species constituted 76 percent of the northern pike diet in the Bay of Quinte.

TABLE 18: Organochlorine concentrations (mg/kg) in whole white suckers from several sites on Lake Ontario, 1983.

	Hamilton	Bronte	Humber	Ganaraska	Brockville
# of fish	18	5	9	5	5
PCB	1.52 ±0.42	1.92 ±1.4	3.39 ±1.22	1.24 ±0.76	1.88 ±1.77
ΣDDT	0.34 ±0.12	0.79 ±1.26	0.53 ±0.29	0.29 ±0.16	0.03 ±0.03
HCB	0.01 ±0.01	0.0 ±0.01	0.01 ±0.01	0.09 ±0.09	0.01 ±0.00
Mirex	0.06 ±0.05	0.05 ±0.01	0.04 ±0.03	0.06 ±0.04	0.09 ±0.07
Dieldrin	0.02 ±0.02	0.02 ±0.02	0.03 ±0.02	0.02 ±0.00	<0.01
αChlordane	0.004 ±0.002	ND	ND	ND	ND

Note: Fish from Hamilton, Bronte, Ganaraska, and Brockville were 5-7 year old males. Humber River fish were 5-7 year old females.
Source: V.W. Cairns, Department of Fisheries and Oceans

Concerns for an edible fishery in Hamilton Harbour must be addressed on a whole lake basis. Many of the non-resident species such as smelt, alewife, salmon and trout accumulate contaminants lake wide and it is unlikely that reduced loadings in Hamilton Harbour will result in an edible non-resident fishery.

Fish Health in Hamilton Harbour

Fish tumour surveys conducted in Hamilton Harbour between 1973 and 1976 reported the occurrence of tumours on bottom dwelling fish such as carp, carp X goldfish hybrids, goldfish, white suckers and brown bullheads (Table 19). These surveys were repeated in 1983-84 to determine if tumour prevalence had changed in the last 10 years, and to compare tumour frequency with other sites in the Great Lakes.

Gonadal tumours in carp and carp X goldfish hybrids: Gonadal tumours occur in carp and carp X goldfish hybrids in Hamilton Harbour (Table 19). The tumours are benign and are found most frequently in older fish. Gonadal tumours are rare in carp (1%) but very common in the carp X goldfish hybrids (100% in older males). Tumoured carp and tumoured and non-tumoured hybrids are sterile.

There has been little change in the occurrence of benign gonadal tumours in carp X goldfish hybrids since 1975. Tumour frequency in five year old male hybrids changed from 60 percent in 1975 (Sonstegard, 1977) to 52 percent in 1983 (DFO, Burlington). Sampling at other locations revealed that gonadal tumours were common in hybrids from upper Lake Huron (Kincardin), Rochester, Long Point on Lake Erie, the Welland River, and the Detroit River. The appearance of tumours at all sample locations, including the relatively clean site in Lake Huron, suggests a non-chemical etiology. The presence of gonadal tumours in carp X goldfish hybrids in Hamilton Harbour is probably not related to contaminant exposure.

Lip and body papillomas on white suckers: Sonstegard (1976, 1977) reported the occurrence of benign papillomas on the lips and bodies of white suckers (Table 19). Although papillomas were found on suckers throughout the lake, fish from Hamilton Harbour (35%) and Sixteen Mile Creek (50%) were the most severely affected. There has been little change in the prevalence of papillomas on white suckers from Hamilton Harbour and Sixteen Mile Creek between 1973 and 1983.

The frequency of occurrence in Lake Ontario ranged from 5 to 60 percent. Prevalence exceeded 30 percent at all sites west of Toronto and in the area of Port Hope (Ganaraska River and Gage Creek) (Table 20). There is no evidence that papillomas are caused by chemical exposure. However, the increased prevalence in suckers from western Lake Ontario suggests a local problem.

The cause of epidermal papillomas on white suckers is unknown. Sonstegard (1977) reported the presence of a C-type virus in the lip papilloma but was unable to induce papillomas by exposing fish to the virus. Papillomas tend to shrink when affected fish are moved to a laboratory environment, suggesting that continued exposure to a biological or chemical agent is necessary to sustain the tumour. Sustained tumour prevalence in Hamilton Harbour between 1973 and 1983 indicates long term continuing exposure to etiological agents.

TABLE 19: Summary of lesions reported in Hamilton Harbour fish.

Species		Lesion	% Occurrence	(N)
White sucker				
	lip	neoplasia	39.0	(1200)
	skin	neoplasias:		
		hyperplasia	0.6	(1200)
		papilloma/carcinoma	1.7	(1200)
	liver	neoplasias:		
		carcinoma	2.7	(113)
		granuloma	4.4	(113)
	gonad	testicular lesions:		
		seminoma	1.4	(71)
		hypertrophy	2.8	(71)
	bladder	fibrosarcoma	1	(113)
Brown bullhead				
	lip	neoplasia	25.4	(480)
	skin	body neoplasia[1]	7.0	(480)
		barbel asymmetry	72.0	(480)
		ulcer	5.0	(480)
	liver	gross anomalies[2]	10.5	(380)
		cholangiolar carcinoma	1.6	(124)
Goldfish				
	skin	ulcer	50-80	(N/A)
	kidney	granuloma	51.0	(29)
		polycystic	6.3	(80)
	gonad	neoplasia	30.0	(13)
Carp				
	gonad	neoplasia	0.9	(220)
Carp X Goldfish				
	gonad	neoplasia	52.0	(79)
		hermaphrodism	6.3	(79)
White perch				
	kidney	glomerular nephritis	100.0	(43)

1: Total number of raised papillomas/carcinomas.
2: A total of 380 livers were observed. One hundred and twenty-four were analyzed histologically. Two were diagnosed as cholangiolar carcinoma.

TABLE 20: Percent occurrence of lip and body neoplasms[1] in white suckers from Lake Ontario. Data from 1981 to 1983.

Site	Lip[2] (N)	Body[3] (N)
Vineland	9 (132)	0
Forty Mile Creek	23 (78)	2.5 (155)
Grindstone Creek	39 (1200)	1.4 (5284)
Spencer Creek	71 (146)	2.7 (146)
Bronte Creek	54 (109)	2.1 (147)
Sixteen Mile Creek	62 (111)	9.4 (160)
Credit River	34 (38)	2.5 (118)
Humber River	40 (58)	0.8 (335)
Rouge River	16 (96)	0.3 (347)
Graham Creek	19 (102)	5.0 (119)
Gage Creek	40 (99)	4.1 (192)
Coburg Creek	15 (102)	2.7 (146)
Bay of Quinte	5 (91)	2.7 (184)
Brockville	15 (177)	7.8 (192)
Lake Huron:		
Maitland River	40 (N/A)	(N/A)
South Bay	5 (280)	(N/A)

1: Neoplasms refer to single or multi-nodular growths. Not all of these lesions were confirmed histologically.
2: Mean percent occurrence for fish 7 years and older.
3: Mean percent occurrence for combined ages.

The widespread distribution throughout Lake Ontario and in Lake Huron indicates that Hamilton Harbour is not the source of papillomas. The occurrence of papillomas in relatively clean sites at levels less than 10 percent suggests a non-chemical etiology.

The papilloma has no noticeable effect on the biology of white sucker populations in Hamilton Harbour. Spawning migrations were monitored in Grindstone Creek from 1980 to 1983. All year classes were represented in the population and there was no significant difference in growth, fecundity, fertility, percent hatch, fry survival and growth, and reproductive behaviour between normal and papillomatous fish (Cairns and Fitzsimons, 1988).

Liver tumours in white suckers: White suckers from Hamilton Harbour are afflicted with liver lesions (Table 19) (Cairns and Fitzsimons, 1987). These included bile duct hyperplasia and low levels of hepatocellular carcinoma. The total prevalence of liver neoplasms in Hamilton Harbour was 2.6%, considerably less than the 7.4% found at Sixteen Mile Creek. Liver carcinomas were also found in white suckers from eight sites tested on Lake Ontario between Forty Mile Creek and the Ganaraska River. There were severe bile duct anomalies but no liver tumours in white suckers from the control site on Manitoulin Island.

The occurrence of liver anomalies at all sites on Lake Ontario and also at the control site suggests a non-chemical etiology.

Hepatocellular tumours were found in white suckers from Hamilton Harbour, Sixteen Mile Creek, and the Humber River. They were not found in fish from the other sites. Hepatocellular tumours are often associated with contaminant exposure in laboratory induction experiments. The limited distribution of this tumour type strongly suggests a chemical association. The chemicals responsible are unknown but there are good data showing that some Hamilton Harbour sediments are heavily contaminated with mammalian carcinogens (PAHs). A tumour induction experiment in which Hamilton Harbour sediment extracts were injected into the yolk sacs of developing rainbow trout fry confirmed the carcinogenicity of the sediments. Twelve percent of the fry developed tumours within 14 months following a single exposure (Metcalfe et al., 1988).

Lip and body papillomas and liver lesions in brown bullheads: The prevalence of lip papillomas in brown bullheads from Hamilton Harbour declined from 80 percent in 1973-76 (sample size unknown) (Sonstegard, 1976) to 25 percent in 1983 (Table 19). This is similar to the percent occurrence reported by Baumann (1987) for bullheads from the heavily polluted Black River in Ohio and from Lake St. Clair.

Body lesions, which occur less frequently (7%) than the lip papillomas, appeared as flat, circular, black or brown plaques, or as raised growths. Fifty-eight percent of the body lesions examined histologically were invasive carcinomas (n=17). Only 1.6% of the brown bullheads had liver carcinomas. This is considerably less than the 80 percent reported for bullheads in the Black River (Baumann, 1987). Seventy-two percent of the barbels (used for sensory stimuli) were reduced to short stubby projections less than 5 mm in length. In some fish the barbel ended in a swollen mass. There are no data from other locations reporting the significance of this finding. However, the occurrence of ulcers and fin rot resulting from contact with contaminated sediments (by infectious or chemical agents) has been reported for marine species (Mearns and Sherwood, 1977).

The cause of epidermal papillomas and carcinomas in brown bullheads is unknown. However, there is some information suggesting that exposure to contaminated sediments may induce papillomas (Black, 1982) and that papillomas increased in fish exposed to sewage effluent (Grizzle and Melitus, 1983). There are good relationships from other sites in Canada and the US between high occurrence of liver tumours and elevated levels of PAHs in sediment. The low level of tumours in Hamilton Harbour bullheads is surprising given the amount of PAH contamination along the south shore. Bullheads tend to remain in the west end of the harbour and exposure to contaminated sediments may be reduced because of limited movement into the most contaminated sites.

III.4.7 Wildlife

Introduction

Historically, the wetlands of Cootes Paradise and Hamilton Harbour provided a haven for thousands of migrant and resident waterbirds and a wide variety of marsh-dependent wildlife, including many commercially important species such as muskrat. However, documentation of this is largely restricted to passages in diaries, newspaper clippings and other writings, many unpublished. Dundas resident Charles Durand (1893) wrote that in 1818-19, Cootes Paradise "was a paradise for game of all kinds. Immense flocks of ducks and wildfowl, and wild animals innumerable in old times were seen there. It was also the resort of wild fur animals, such as the otter, perhaps beaver, fisher, minks and especially muskrats; snakes were abundant there of all kinds". In 1861, Thomas McIllwraith, a prominent Hamilton area ornithologist, described flocks of waterfowl in Hamilton Harbour "so great as frequently to darken the light of the sun by day, and make the night hideous with their discordant cries".

Though superficial, these accounts do give an indication that wildlife in the area was of very different character than it is today. The most comprehensive attempt to define those changes, with particular reference to waterbirds, was recently prepared by the Canadian Wildlife Service (CWS, 1986). Trends have emerged from the analysis which indicate that more species were common residents of the Harbour before 1948 (Dobos, 1986).

Undoubtedly, the loss of marsh habitat has had a profound effect on the composition, distribution and/or abundance of wildlife communities in Cootes Paradise and Hamilton Harbour. Waterfowl, rails, grebes, muskrats, and bullfrogs are all highly dependant on wetland vegetation for food, shelter, loafing and nesting. By 1979, an estimated 74% of shoreline marshes of Hamilton Harbour and Cootes Paradise had disappeared in the previous 150 years (Whillans, 1982). A further reduction in marshes has occurred since 1979 to an estimated 50 hectares in 1985 of the original 500 hectares. While the impact of these habitat reductions on wildlife in both Cootes Paradise and Hamilton Harbour is currently only partially understood and documented, the available information shows that many marsh-dependant wildlife species have either declined or have completely died out.

Geographically the Cootes Paradise/Hamilton Harbour area lies within two broad and overlapping life zones: the Great Lakes-St. Lawrence and the Carolinian. Consequently, the flora and the fauna reflect elements of both of these major biomes.

The Stakeholders have identified the open water area of Hamilton Harbour and 5 shoreline areas within the basin as having significant wildlife associations and therefore requiring protection/enhancement in the RAP (Hamilton Harbour Stakeholders, 1986). The current status of the wildlife communities will be discussed in detail for each sub-area within the Harbour.

Sub-area Physical Descriptions

Cootes Paradise: Cootes Paradise is an 840 hectare wildlife sanctuary located at the extreme western end of Hamilton Harbour. The santuary is managed and almost wholly owned by the RBG. It has been classified by OMNR as a Class I wetland (MNR, 1987), an Area of Natural and Scientific Interest (ANSI) and is a Hamilton Region Conservation Authority Environmentally Sensitive Area (ESA). The Canadian Wildlife Service has described Cootes Paradise as an important waterfowl staging area in Lake Ontario (Dennis et al., 1984). It is important on a regional, provincial, national and international scale.

Cootes Paradise is comprised of roughly 50% terrestrial upland habitat and 50% wetland habitat. The vegetation of the uplands is primarily climax forest with maple and oak predominating. Marsh vegetation comprises approximately 20% of the total wetland area, the remainder being open water. The shoreline is deeply indented, particularly on the south shore where numerous wooded ravines terminate in small coves or inlets. There are four major hydraulic inputs (Hopkins Creek, Chedoke Creek, Spencer Creek, and the town of Dundas STP).

Hendrie Valley/Carroll's Point: Hendrie Valley/Carroll's Point is an area of approximately 150 ha located in the lower reaches of Grindstone Creek. The creek is a major watercourse whose headwaters originate above the escarpment in Flamborough and flow south from Waterdown. The Royal Botanical Gardens owns and manages the area, including the Carroll's Point water lot. This area has been designated an ESA in Halton Region. The vegetation is mixed deciduous forest on the slopes, with a small portion of open wet meadow and marshy bottomland where several small ponds vegetated with cattail and manna grass are located.

Pier 27 (Tollgate Ponds): Pier 27 is an area of approximately 28 hectares in the southeast corner of Hamilton Harbour currently utilized for contaminated Harbour dredgate disposal by the Hamilton Harbour Commission. It is composed of two large ponds surrounded by rubble berms, and is gradually being filled with dredgate. The berm at the less disturbed north end is vegetated with shrub willows (Salix sp.) and young eastern cottonwood trees (Populus deltoides). This area has been designated an ESA in Hamilton-Wentworth Region.

Hydro Islands: The Hydro Islands are located in the northeast corner of Hamilton Harbour and consist of two stone islands once constructed to provide foundation for large hydro transmission towers. The towers have been removed from the islands. The islands provide breeding habitat for a large colony of Common Tern. The Hydro Islands have been designated an ESA in the Hamilton-Wentworth Region.

Windermere Basin: Windermere Basin is a 40 hectare, shallow (0.7-1.0 m) water basin, located at the southeast corner of the Harbour. It receives hydraulic inputs from Red Hill Creek, Stelco, and the Hamilton STP.

Van Wagner's Ponds: The area known locally as the Van Wagner's Ponds (or Van Wagner's Marsh) is a significant natural wetland in the Hamilton area. It includes the marsh area near the mouth of Red Hill Creek on the south side of the QEW, and the two ponds on the north side of the QEW, and is one of few

remnants of the once extensive shoreline marshes of Lake Ontario.

Birds

Cootes Paradise: Though detailed information exists at RBG for terrestrial bird species, the present discussion is confined to waterbirds. It is sufficient to point out that breeding bird densities and species diversity are higher in the terrestrial habitats of the north shore when compared with those of the wetland habitats.

The marshes that border the west end of Cootes Paradise contain breeding rails, coots and marsh wrens in small numbers, some species of which breed rarely in this region. West Pond is also frequented by several species of dabbling ducks, principally, American black duck (Anas rubripes), common merganser (Mergus merganser), and in the deeper canal, hooded merganser (Lophodytes cucullatus) during migration. There is also some evidence that wood ducks, (Aix sponsa) blue-winged teal (Anas discors) and Canada geese (Branta canadensis) still breed in this area in small numbers and in 1977 the last known breeding attempt of the black tern (Chlidonias niger) reportedly occurred here. Herons and egrets regularly feed in West Pond. The remnant marsh which borders the south side of Spencer Creek willow line still provides breeding habitat for small numbers of bitterns, rails and marsh wrens. A small pond formed by a break in marsh vegetation contains concentrations of waterfowl especially during spring migration, and affords good feeding areas for herons particularly the black-crowned night heron, (Nycticorax nycticorax).

On the north side of the Spencer Creek willow line, heavy autumn concentrations of dabbling ducks, principally, green-winged teal, (Anas crecca), mallard (A. platyrhynchos), gadwall (A. strepera) and wood duck occur. In addition osprey (Pandion haliaetus), herons and egrets are frequently seen feeding during migration.

At the end of the willow line, during low water years, an extensive mudflat is created. During 1984/85 a total of 27 species of shorebirds were recorded. This is considered one of the best areas in southern Ontario to observe shorebirds in the fall. In addition, it is an excellent feeding area for herons, egrets and all species of dabbling ducks, especially green-winged teal and northern pintail (A. acuta). The mudflats are also known for large concentrations of loafing terns and gulls. Seven species of the latter were recorded in 1984/85.

The central open water area of Cootes Paradise is principally used by migratory ducks, especially diving ducks. This is the only area in Cootes Paradise that common loons, (Gavia immer), red-necked grebes (Podiceps grisegena) and horned grebes (P. auritus) are recorded. During the fall and early winter, large numbers of common mergansers are observed feeding in this area until Cootes freezes. The old Desjardin Canal pilings provide an important preening location for double-crested cormorant (Phalacrocorax auritus), common terns (Sterna hirundo), herring gulls (Larus argentatus) and great black-backed gulls (Larus marinus).

The aquatic areas at Princess Point/Chedoke Creek mouth are important

waterbird concentration areas. In early spring, open water attracts early migrant waterfowl. In the fall, when water levels are lower, there are large numbers of dabbling ducks, especially gadwall and American black duck. As well, gulls and a variable number of Canada geese congregate during the fall.

There are a number of smaller remnant marshes which rim Cootes Paradise shoreline and they provide limited breeding habitat for a small number of regionally rare species such as the sora rail (Porzana carolina) and least bittern (Ixobrychus exilis).

Hendrie Valley/Carroll's Point: Waterbird usage of this area has three principal concentration points. A small patch of cattail near the Desjardin Canal supported two species of breeding birds in 1984: the mute swan (Cygnus olor) and common moorhen (Gallinula chloropus). Both species are rare in the region. The open water in Carroll's Point bay is heavily utilized by nesting and migrating waterfowl. Diving ducks are very common here during spring and fall. During the winter, loafing gulls, particularly greater black-backed gull, and glaucous gull (Larus hyperboreus) are associated with this area. At the mouth of Grindstone Creek, when low autumn water levels expose mudflats, many species of shorebirds, such as the common snipe (Capella gallinago), congregate. This area is heavily utilized for feeding by black-crowned night heron, osprey, and dabbling ducks, particularly gadwall.

Pier 27: The most outstanding feature of this area is the density and diversity of nesting colonial birds. The cottonwood trees provide nesting sites for a large colony of black-crowned night herons. The night heron colony has been expanding steadily since 1975 when six nests were discovered (North, 1975). In 1987, the colony contained 212 active nests. The first cormorant nest was found on the ground in 1984. Since 1985, they have increased dramatically in the cottonwood trees to 51 nests in 1987. The first nesting of the snowy egret (Egretta thula) in Canada occurred here in 1986 (Curry and Bryant, 1987).

The berms and filled cells of the containment area support a large ring-billed gull (Larus delawarensis) colony, which numbered over 21,000 nests in 1987. This is one of the largest gull colonies on the lower Great Lakes. About 200 herring gull nests, 150 common tern nests and 134 Caspian tern (Sterna caspia) nests are located around the gull colony. The nesting of common terns is regionally significant. The Caspian tern is considered to be a rare species in Ontario and Canada (Cadman et al., 1987).

Other species which nest on the berms around the ponds are Canada goose, mallard, gadwall, spotted sandpiper (Actitus macularia) and killdeer (Charadrius vociferus). Species which have nested in the past include green-winged teal, marsh wren (Tetmatodytes palustris), common moorhen and American coot (Fulica americana); all are regionally significant breeding species.

The ponds are used for staging by large numbers of migratory waterfowl in the autumn. Many species of shorebirds feed at the mudflats along the shores of the ponds during late summer and autumn, including several species rare to Ontario, such as the American avocet (Recurvirostra americana) and willets (Catoptrophorus semipalmatus) in 1987 (Jennings, 1987).

Hydro Islands: Members of the Ontario Bird Banding Association banded 552 nesting terns and counted over 200 nests from these two small islands in 1985. During the late summer and early fall double-crested cormorants use the islands for resting and preening.

Windermere Basin: Local naturalists know this area to be regionally significant for waterfowl during the autumn and winter. Waterbird surveys of the Basin were conducted by CWS in the autumn of 1986. The average number of birds present per count was 1867, with the most numerous species being Scaup (Aythya sp.), American black duck, mallard, and bufflehead (Bucephala albeola) (Dobos and Weseloh, 1987). Average numbers of waterbirds during winter surveys increased to 4648 birds per count. Regionally significant species of waterfowl, which overwintered at the Basin, include green-winged teal, northern pintail, northern shoveler (Anas clypeata), redhead (Aythya americana), hooded merganser and ruddy duck (Oxyura jamaicensis).

During low water periods in the late summer and autumn, migrating shorebirds including species rare in Ontario are attracted to the exposed sludge bank in large numbers. Recent rare sightings include a piping plover (Charadrius melodus) (Jennings, 1986a), an endangered species, and an American oystercatcher (Haematopus palliatus) (Jennings, 1986b) (only the second record for Ontario).

Areas of marsh vegetation along the shore of Windermere Basin are the only remnants of the once extensive marshes of Hamilton Harbour. These areas provide nesting habitats for several bird species including mallard, gadwall, American black duck, green-winged teal, and common moorhen. At least 30 broods of waterfowl were observed there during the summer of 1987.

Van Wagner's Ponds: This area has substantial areas of emergent aquatic vegetation (mostly cattail) which provide nesting habitat for a number of regionally significant bird species. It also has extensive submergent aquatic vegetation (pondweed and water lilies) which provides food for a large number of waterbird species.

The black tern, a provincially rare breeding species, has nested here for many years. The last recorded nests were in 1986. Since 1978, this area has been the only nesting site in the region. The least bittern, another provincially rare breeding species, has also nested here in recent years. This area is one of two regional breeding sites. The green-backed heron, common moorhen and pied-billed grebe, all regionally significant breeding species, have nested at Van Wagner's Ponds. Other marsh birds regularly use the area as a feeding site, such as great blue heron, great egret, black-crowned night heron, Virginia rail, sora rail, American coot, Caspian tern, common tern, belted kingfisher, and marsh wren. Some of the rare marsh birds seen here include eared grebe, snowy egret and Forster's tern.

The Van Wagner's Ponds are an important staging area for migratory shorebirds and waterfowl. During periods of low water levels, exposed mudflats attract at least 25 species of shorebirds, including rare species such as willet, Hudsonian godwit, western sandpiper, and piping plover (an endangered

species). Waterfowl which regularly use the ponds include all of the regular puddle duck species, plus redhead, lesser scaup, and hooded merganser.

The Van Wagner's Ponds area is a migration point for landbirds as well. This area provides an island of habitat for birds which migrate along the shore of Lake Ontario. Several rare species, including bald eagle, merlin, peregrine falcon, little gull, yellow-billed cuckoo, snowy owl, black-backed woodpecker and western kingbird, have been observed there. The terrestrial habitat around the ponds also provides breeding habitat for many common species of birds.

Hamilton Harbour Proper: Hamilton Harbour has a diverse and abundant waterbird population associated with it. CWS waterbird surveys in the autumns of 1985 and 1986 recorded approximately 1200 birds per count composed of up to 43 species (Dobos and Weseloh, 1987). Birds were generally concentrated in groups at specific locations around the Harbour. The LaSalle Park Marina, the Hamilton marinas, and the northeast shoreline areas had the greatest numbers of birds per survey. The western end, Lax landfill, LaSalle Park Marina and the northeast shoreline areas had the greatest number of species of waterbirds. The steel factory shoreline, the centre of the Harbour, the Burlington residential shoreline, and the highway and railway shorelines had the fewest numbers and species.

One of the best spring and fall concentrations of waterfowl, namely scoters (Melanitta sp.), tundra swans (Olor columbianus) and mergansers, is located directly below the Woodland Cemetery near the northwest shore.

Contaminants in Birds

The earliest studies of contaminants in birds from Hamilton Harbour date from 1970 when Gilbertson (1972) reported HCB, dieldrin, DDE and PCBs in common tern (Sterna hirundo) eggs from the Hydro Islands. This was the first reported instance of HCB in avian tissue. In 1971, Gilbertson (1974) conducted further investigations which showed that the terns which nested on the Hydro Islands returned in the spring relatively free of contaminants but the residue levels in their eggs increased with later dates of laying. Eggs laid in June had higher contaminant burdens than those laid in May. He also discovered deformities, suspected of having been mediated by contaminants, among terns nesting on those islands (Gilbertson et al., 1976).

Few studies were conducted within the Harbour itself during the remainder of the 1970s. Herring gull eggs from the Harbour were sampled in 1981, 1982, 1984 and 1986. In 1981, DDE, PCBs and Mirex levels were 11, 79 and 1.9 mg/kg (wet weight), respectively, whereas in 1986, those same contaminants were 4.0, 25 and 0.71 mg/kg, a reduction of 63 - 68% (CWS, data files).

In 1981/82, a Lake Ontario-wide survey was done of contaminant levels in herring gull eggs. Eggs from 8 Lake Ontario sites, including Hamilton Harbour, showed no significant variation in contaminant levels among sites (except for one compound at one site) (Weseloh and Struger, 1985). In other words, contaminant levels in herring gull eggs from Hamilton Harbour were neither significantly higher nor lower than those from other Lake Ontario sites. In a 1983 study of lead, cadmium and mercury levels in herring gulls from four Great Lakes sites, adult gulls from the eastern Harbour had the highest levels in 25%

of the cases. Kidney levels of lead and cadmium were 6.90 and 2.16 mg/kg (wet weight), respectively, and liver levels of mercury were 1.36 mg/kg. Eggs and young of herring gulls nesting at Pier 27 had elevated levels of both organics and heavy metals, when compared to Great Lakes samples (CWS, data files; Struger et al., 1987).

However, the recent breeding success of several colonies of fish-eating birds in the Harbour, including common terns, is cause for guarded optimism. It should also be noted that levels in gulls probably represent the integretion of levels in food from distances within 5 - 10 miles from the colony site. Thus levels in Hamilton Harbour gulls are not indicative of only Hamilton Harbour.

It is paradoxical that some populations of water birds congregate in the east end of Hamilton Harbour where the sediments are known to be contaminated with organics and heavy metals, and the habitat has deteriorated to a point where it is substandard at best. Many birds breed in the area during the spring and are attracted to the area for migrational staging and overwintering. Wildlife in this area has been shown to accumulate high levels of contaminants and to suffer significant health problems. Many of the birds ingest highly contaminated food. In a 1986 study, flightless domestic ducks were released into Windermere Basin and two other sites. Those at Windermere accumulated PCB residues almost 50 times greater than ducks at the other locations. Lead levels were also greatly elevated in Windermere Basin birds compared to those from the other sites. There are strong suggestions that lead was the prime causative factor in the die-offs of both the domestic ducks and an earlier case involving wild ducks at Windermere (CWS and MOE, unpub. data). This area produces or has the potential to produce contaminated birds and other wildlife, and this condition should not be allowed to persist.

Studies undertaken by MNR will also document contaminant levels in resident wild mallards in Hamilton Harbour and in waterfowl reared in Windermere Basin, and the results will be compared with several other IJC areas of concern.

Specific Concerns for Bird Populations

Migratory bird species, in addition to being exposed to the cumulative effects of contaminants, must cope with a dwindling but vital food supply during migration. Surveys by CWS indicate that the remaining marshes along the Lake Ontario shoreline are extremely valuable as waterfowl concentration areas in spring and fall (Dennis and Chandler, 1974). Therefore, any efforts to expand food production in the remaining marshes will have a beneficial effect on waterbirds. Some adaptable birds, mainly scavengers, have benefitted from habitat alterations, and now numerically dominate the resident wildlife community structure.

The major concerns for wildlife in the eastern Harbour area are: 1) the occurrence of heavy metals and toxic organics in the sediments of Windermere Basin, in the surficial sediments of the Harbour, and in the confined disposal facilities (CDFs) of the Hamilton Harbour Commission; 2) the impact of these contaminated sediments upon wildlife; 3) the future development plans (resulting in habitat loss) for Windermere Basin and areas known locally as the

Hydro Islands and Pier 27.

The dredging plan for Windermere Basin is evolving in a manner that may provide for wildlife concerns. At Pier 27, property owned by the Hamilton Harbour Commission, the future is not yet assured. The Commissioners have said that they have no plans for the area for the immediate future, i.e. 10 - 15 years. However, eventually they may want to put warehouse facilities, or some similar development, on the site. That development would displace the nesting colony of some 25,000 pairs of gulls, terns, herons and cormorants which currently breed there. The question is, given the long lead time before development is to take place, could the birds be encouraged to move to some other nearby, man-made or natural, nesting area? And if so, where, when and how? Less desirable species, like ring-billed gulls, will almost certainly move with little or no problem. However, for other species which are more sensitive to disturbance, e.g. Caspian terns, there is no known precedent for "moving" them from one site to another.

Herpetiles

Cootes Paradise: Significant concentrations of frogs and turtle species still occur in many localized wetland habitats. Frogs are especially abundant wherever vegetation remains flooded throughout spring and fall. The northern leopard frog (Rana pipiens) and American toad (Bufo americanus) are the most common species and are well distributed in all marshy areas, but especially abundant in the old Spencer Creek bed. The green frog (Rana clamitans melanota) also occurs here. The western chorus frog (Pseudacris triseriata) is uncommon and found in small patches of marsh vegetation.

Turtle populations in Cootes Paradise are high in species diversity and abundance. The preferred areas of concentration are those which provide good basking sites and readily available food such as in the old Spencer Creek bed, Westdale Inlet and backwater ponds at the extreme western end. One of the latter ponds rivals other sites in North America as the highest estimated density of the midland painted turtle (Chrysemys picta marginata). Similarly, snapping turtle (Chelydra serpentina) densities in the western end of Cootes are considered very high, when compared to other sites, especially during breeding season in early June, when many females seek a suitable substrate for egg laying. The shoreline in this area provides good opportunities for this activity, and it is likely that the largest segment of the population in the western end resides there. Small populations of turtles such as Blanding's (Emydoidea blandings), found only in the old Spencer Creek bed, have quite restricted distribution, while a regionally uncommon species of the map turtle (Graptemys geographica) occurs in fair (20-30) numbers in Westdale Inlet.

Hendrie Valley/Carroll's Point: Reptile and amphibian populations of the area are characterized by species which are local or regionally significant. For example, both bullfrog (Rana catesbeiana) and pickerel frog (R. palustris) still occur in backwater ponds bordering the lower Grindstone Creek, albeit in restricted numbers. In addition, there is a large population of map turtles present, and an eastern spiny soft shell turtle (Trionyx spiniferus spiniferus) was sighted on two occasions in 1984 and one specimen was caught in 1982. This latter species is considered extremely rare and, at one time, was thought

to have been extirpated from Lake Ontario (Campbell, 1977).

Windermere Basin: Other wildlife known to occur in the Basin include muskrat, eastern cottontail (Sylvilagus floridanus), ring-necked pheasant (Phasianus colchicus), midland painted turtle and common snapping turtle.

Van Wagner's Ponds: The abandoned railway bed which bisects the ponds provides nesting sites for common snapping turtles and midland painted turtles.

Contaminants in Turtles

In a study of organochlorine levels in snapping turtle eggs from 10 sites in southern Ontario, eggs from Hamilton Harbour had the highest levels of PCBs (8.59 mg/kg, wet weight), oxychlordane (0.074 mg/kg), trans-nonachlor (0.02 mg/kg) and dieldrin (0.06 mg/kg) (Struger et al., 1989). The significance of the contaminants in the snapping turtles is unknown; although in another study, hatching deaths and deformities were correlated with levels of chlordane (Bishop, CWS, pers.comm.). Hatching deaths and deformities were examined at five sites (Hamilton Harbour, Lynde Shores Creek (Whitby), Cranberry Marsh (Whitby), Long Point (Lake Erie), and Algonquin Park. Hatching deaths were approximately 40% at both Hamilton Harbour and Lynde Shores Creek compared to 10% at the other sites. Deformities, however, were highest at Cranberry Marsh (28%) compared to the other sites (0-2%). In 1986, snapping turtle egg contents from Hamilton Harbour were significantly more contaminated with the pesticides pp'DDE, HCB, α-chlordane and trans-nonachlor than those from Long Point, Algonquin Park and Cranberry Marsh. However, the HCB and PCB concentrations in eggs from Hamilton Harbour and Lynde Shores Creek were similar. This suggests that turtles in sites such as Hamilton Harbour and Lynde Shores Creek, which are connected to Lake Ontario, are subject to contaminants from the Lake.

Mammals

Cootes Paradise: Sixteen species of large mammals occur here. They range from a small mobile herd of less than 20 white-tailed deer (Odocoileus virginianus), which roam freely in distinct travel corridors between the north shore of Cootes Paradise and the Niagara Escarpment, to a large and well distributed population of raccoon (Procyon lotor), which intermixes with high density housing on the south shore. The principal semi-aquatic mammals are mink (Mustela vison), muskrat (Ondatra zibethica) and beaver (Castor canadensis). One beaver was recorded living in a bank den in the lower reaches of Spencer Creek in 1984. The muskrat population, estimated at less than 100 individuals, is confined to small localized pockets of emergent vegetation, primarily cattail (Typha sp.) and manna grass (Glyceria maxima), which rim the Cootes Paradise basin. Muskrats are concentrated in west pond and in bank dens along Spencer Creek. Mink are present in unconfirmed numbers and are commonly associated with the streams of the north shore.

Hendrie Valley/Carroll's Point: Muskrats are found along the Grindstone Creek wherever suitable habitats exist. Bank dens and lodges in the ponds are currently utilized. In 1984, 30 individuals were counted and in 1985, 17 individuals were live-trapped along the creek. Mink were confirmed in 1984 but not quantified.

IV DESCRIPTION OF POLLUTANT SOURCES

IV.1 Point Sources

Pollutant sources are commonly classified as point or non-point sources. For Hamilton Harbour, point sources include municipal STPs, direct industrial outfalls, and combined sewer overflows (CSOs). The non-point sources are urban and rural run-offs, atmospheric and agricultural loadings, contaminant spills, and leachate from landfill sites. In situ loadings which relate to the release of contamination from in-place sediments are also considered in this section. Municipal and industrial loadings of pollutants have been reduced by 60-95% since the early 1960s.

IV.1.1 Municipal

Four municipal sewage treatment plants (STPs) discharge treated wastes to Hamilton Harbour. All are conventional activated-sludge plants with chemical treatment for phosphorus removal. All four plants are well operated.

The Woodward Avenue plant in Hamilton is the largest, serving a population of about 360,000. Sewage from the cities of Hamilton and Stoney Creek and the Town of Ancaster is treated at the plant. It has a design capacity of 409,000 cubic metres per day and is now treating about 320,000 cubic metres per day. The treated effluent is discharged to Redhill Creek as it flows into Windermere Basin of Hamilton Harbour.

The Skyway plant in Burlington serves a population of about 120,000. The sewage from the total urban area of Burlington is treated at the plant. It has a design capacity of 93,000 cubic metres per day and is now receiving about 71,000 cubic metres per day. The treated effluent is discharged into the northeast corner of Hamilton Harbour.

The Dundas plant treats the sewage from a population of about 19,500. The plant has a design capacity of 18,000 cubic metres per day and is now treating a sewage flow of about 11,000 cubic metres per day. Sand filters were recently installed to further treat the final effluent. The treated effluent from the plant is discharged to Cootes Paradise.

The Waterdown plant serves a population of about 4,000 and is treating the sewage from the Community of Waterdown. The plant has a design capacity of 2,730 cubic metres per day and is now treating a sewage flow of 2,400 cubic metres per day. It operates in the extended aeration mode and has sand filters for polishing the final effluent. The treated effluent is discharged to Grindstone Creek.

IV.1.2 Industrial

The two steel mills discharge treated wastewaters to the Harbour. Small quantities of uncontaminated cooling water are discharged by several smaller industries located near the Harbour. All other industries discharge their wastewaters to the municipal sewers for treatment at the municipal sewage

treatment plants.

In 1986, Stelco discharged about 1,057,000 cubic metres per day of treated effluents to the Harbour through five outfalls, while Dofasco discharged about 655,000 cubic metres per day through five outfalls (MOE, 1987d). Control facilities installed by the steel mills include ion exchange for chromium removal, chemical treatment plants for oil and solids removal, steam distillation for ammonia removal, biological treatment for phenols and cyanide removal, clarifiers and dual-media filters for suspended solids removal, and recirculation to reduce flows and, therefore, effluent loadings. These control facilities have been found to be efficient in removing priority pollutants by the conventional parameters.

IV.1.3 Combined Sewer Overflows (CSOs)

Sewage and storm water runoff are collected in a combined sewer system in most of the City of Hamilton. As a result, during periods of high runoff the combined sewer system becomes overloaded and raw sewage overflows into the receiving waters at 26 locations. The Regional Municipality of Hamilton-Wentworth has installed a holding tank at the largest of the combined sewer overflows to collect the sewage overflow. After the runoff event the collected sewage is diverted back into the sewer system for treatment at the municipal sewage treatment facility. The holding tank is designed to collect the total overflow during most summer storm events and to act as a primary clarifier during extended periods of runoff such as occur in the spring. This holding tank, which is located at the Greenhill Avenue combined sewer overflow, was placed in operation in 1988. Combined sewer overflows (86,000 m^3/day) are a source of ammonia and phosphorus, bacteria and suspended solids. The estimated 1987 ammonia and phosphorus loading from combined sewer overflows are 200 kg/day and 90 kg/day, respectively.

IV.2 Non-point Source Loadings to Hamilton Harbour

IV.2.1 Atmospheric

The atmospheric loading was estimated using the deposition rates of various compounds (kg/km^2/yr) from Kuntz (1980) and IJC Great Lakes Science Advisory Report (1980) for Lake Ontario and the Harbour's water surface. Table 21 summarizes the estimated atmospheric loading and compares it to the loadings from point sources. The atmospheric loadings have been calculated for only the Harbour's water surface. Stormwater runoff from the watershed will increase the contribution of atmospheric loading reported in Table 21.

The relative importance of atmospheric loading to point source loading depends on the compound. Atmospheric loadings of inorganic compounds are insignificant, and of trace organics significant, relative to point source loadings.

IV.2.2 Agricultural

Very little is known quantitatively of agricultural or other rural

TABLE 21: Estimated atmospheric loadings to Hamilton Harbour (kg/day), compared with an estimated percent of the point source loadings.

	Atmospheric Loading	Estimated % of Point Source Loading
Phosphorus	1.18	0.2
Ammonia	17.7	0.2
Copper	0.24	3
Iron	4.4	0.06
Lead	0.88	4
Zinc	3.5	2
PCBs	0.007	18
α-BHC	0.002	130
γ-BHC	0.011	180
PAHs	0.116	6
DDT	0.0004	10
Dieldrin	0.0004	>200
Endosulfan	0.006	-
HCB	0.001	15

loadings to Hamilton Harbour. Relative to municipal and industrial loadings, agricultural loadings of contaminants are thought to be small. Loadings of suspended solids from the watershed are important but the relative contribution of agricultural, urban, and in-stream erosion sources is unknown. A land use survey was conducted in 1988 to provide the first step in developing this information (Ecologistics, 1988). Sediment loadings are greatest for agricultural areas in the Spencer Creek watershed below Christie Reservoir, for intensively cropped land south of Hamilton, and in the north part of the Grindstone Creek watershed.

IV.2.3 Dissolved Solids

The total loading of dissolved solids to Hamilton Harbour from all sources was estimated to be 607,000 kg/day in 1977 (Snodgrass, 1981). The use of road salt in 1976-77 was approximately 26 x 10^6 kg for Hamilton and Halton. Therefore, road salt represents approximately 12% of the annual load of total dissolved solids. Red Hill Creek has the highest natural dissolved content of all the major streams.

IV.2.4 Shipping and Spills

Spills in the Harbour are a relatively minor source of pollution. Between 1974 and 1986, there were only seven significant ship-related incidents reported. One was of bunker "C" and the rest were of light oil, ranging from 0.1 to 3 metric tonnes in size. In all cases, 60-90% of the oil was recovered by skimmers and absorbants. Numerous slicks are observed on the water, but since oil spreads rapidly to a thin sheen, sometimes only 1 molecule thick, these slicks represent very small quantities.

Spills from other sources are more frequent. During the same 12 years, sixty-four incidents from land-based activities were reported. Half of these involved oil and the rest a wide variety of industrial liquids. More hydrochloric acid was released than any other product: a total of 950 metric tonnes in 8 accidents. Acids and some other chemicals mix easily with water and cannot be recovered.

The spill records kept by DOE since 1974 indicate that the number and volumes of spill incidents are dropping in response to tougher regulations and preventive and educational programs. All spills from industries are investigated to determine the cause and to ensure that measures are taken to prevent a recurrence. As well, detailed hazardous operations analyses are being carried out to identify where things may go wrong so that preventive measures can be taken to minimize upsets.

IV.3 In Situ Loadings

Elevated concentrations of metals in the bottom waters of the Harbour due to release from the sediment has not been observed except for manganese and, occasionally, iron. Trace organic contaminants have a high affinity for sediment surfaces and are usually insoluble in water. Therefore, organic contaminants located in the sediments will also remain associated with the sediments and will not generally be released into the water column.

IV.3.1 Sediment Phosphorus Release

In many lakes, sediments release nutrients into the overlying water and this release can be the dominant nutrient flux (Ryding, 1985). However, the Hamilton Harbour sediments are not presently considered an important source of nutrients to the water column. Phosphorus release from the sediments has not been observed in the Harbour (MOE, 1986a), neither in short-term equilibrations with Harbour sediment (Mudroch and Sandilands, 1980), nor in long-term anoxic laboratory incubations with Harbour sediment (K. Burnison, NWRI, pers. comm.). Sediment phosphorus release was observed in sediment cores that were bubbled with nitrogen or oxygen. The phosphorus release rates measured over a two month period were equivalent to one to two weeks of external loading of phosphorus. Currently, sediment phosphorus release is assessed as a minor source of phosphorus.

The high concentrations of nitrate or iron in the Harbour may account for this lack of an anticipated release of phosphorus from anoxic sediments. High iron concentrations have been found to reduce phosphorus release in anoxic sediments (Nordin, British Columbia MOE, pers. comm.).

IV.3.2 Sediment Oxygen Demand

Mudroch and Sandilands (1980) found that ammonia was readily released from sediments into the Harbour water but this release is probably insignificant relative to the external loading of ammonia. However, if the sources of ammonia to the Harbour are treated with the best available technology, then the sediment release of ammonia will become important in delaying the oxidation of

the hypolimnion. Bacteria consume oxygen to oxidize ammonia.

The sediment oxygen demand accounts for a small portion of the total oxygen demand; 40% in spring, 10-20% in summer, and 25% in the fall (MOE, 1985). As the restoration of the Harbour proceeds, sediment oxygen demand will delay the oxygen response of the Harbour. Eventually the sediments could become oxidized, but the period of time required for this to occur is unknown. An estimate of 10 years has been suggested.

IV.4 Summary of Loadings by Contaminant

IV.4.1 Hamilton Harbour

Ammonia Loading

Major reductions in industrial discharges of ammonia have been achieved. The industrial loadings have been reduced from about 24,000 kg/day of ammonia as nitrogen in 1967 to about 857 kg/day in 1987. However, there has been little change in the loadings of ammonia from the municipal STPs. Regular monitoring for ammonia in the effluents from the STPs was started in 1978.

Figure 14 shows the total loadings of ammonia as nitrogen from both industrial and municipal sources since 1978, including estimates of loadings in Hamilton's CSOs and the concentration of ammonia found in the Harbour. The concentration trend in the Harbour is cyclical with the highest concentration occurring in the early spring and the lowest in the summer. The nitrifying bacteria which oxidize the ammonia are inhibited by cold temperatures. As a result, ammonia builds up in the Harbour during the winter. In 1987, the concentration peaked at 1.5 mg/l. When the water temperature warms above 6°C in spring, the nitrifying bacteria become active again and very rapidly oxidize the accumulated ammonia. In so doing, the oxygen level in the Harbour water is reduced. The oxidation of each mg of ammonia, as nitrogen, requires about 4.6 mg of oxygen.

Not all of the ammonia discharged to the Harbour is oxidized. Ammonia is also flushed to the lake through the canal. As well, some ammonia is used by the aquatic biota as a nutrient. It is initially taken up by aquatic plants, including algae, and by bacteria. A small portion of this nitrogen makes its way through the food chain, ending up as protein in fish and water fowl.

A plot of annual average ammonia loadings to the Harbour versus maximum early spring concentrations in the main body of the Harbour is shown in Figure 15. Extrapolation of the best fit straight line through the points in the plot to the 0 mg/l ammonia concentration indicates that during the winter about 3,600 kg/day of ammonia might be utilized by algae or is flushed out into Lake Ontario. Therefore, at the present rate of removal, a further 4,200 kg/day reduction in ammonia loading may prevent the build up of ammonia in the Harbour during the winter. This would be, therefore, a first loading target.

Ammonia in the un-ionized form is toxic to some aquatic organisms. The percent of ammonia present in the un-ionized form is dependent on the pH and the temperature of the water (Table 22).

Figure 14

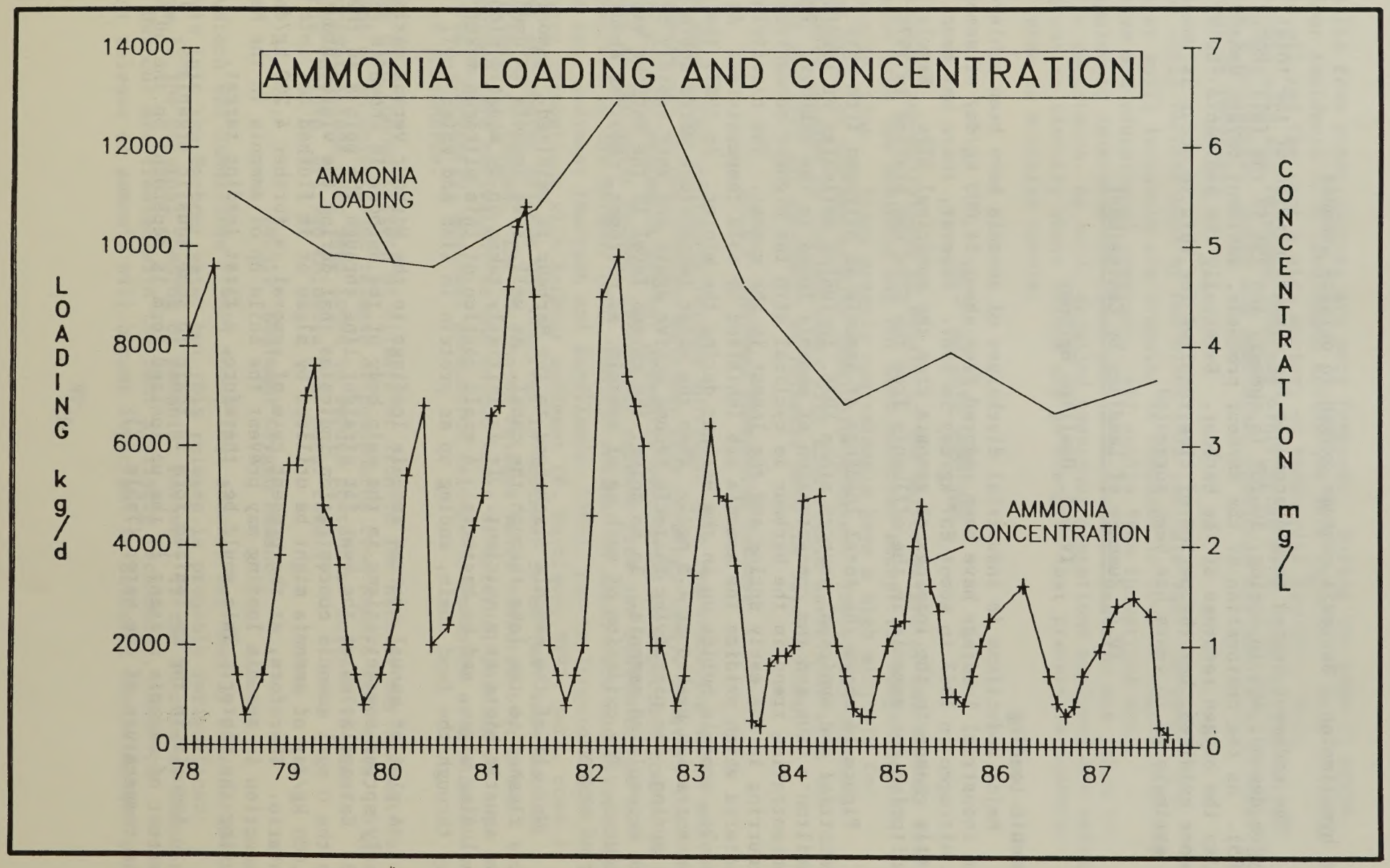

AMMONIA LOADING AND CONCENTRATION
AMMONIA LOADING
AMMONIA CONCENTRATION
LOADING kg/d
CONCENTRATION mg/L
14000
12000
10000
8000
6000
4000
2000
0
7
6
5
4
3
2
1
0
78
79
80
81
82
83
84
85
86
87

Figure 15

Annual average ammonia loading vs. maximum spring concentration

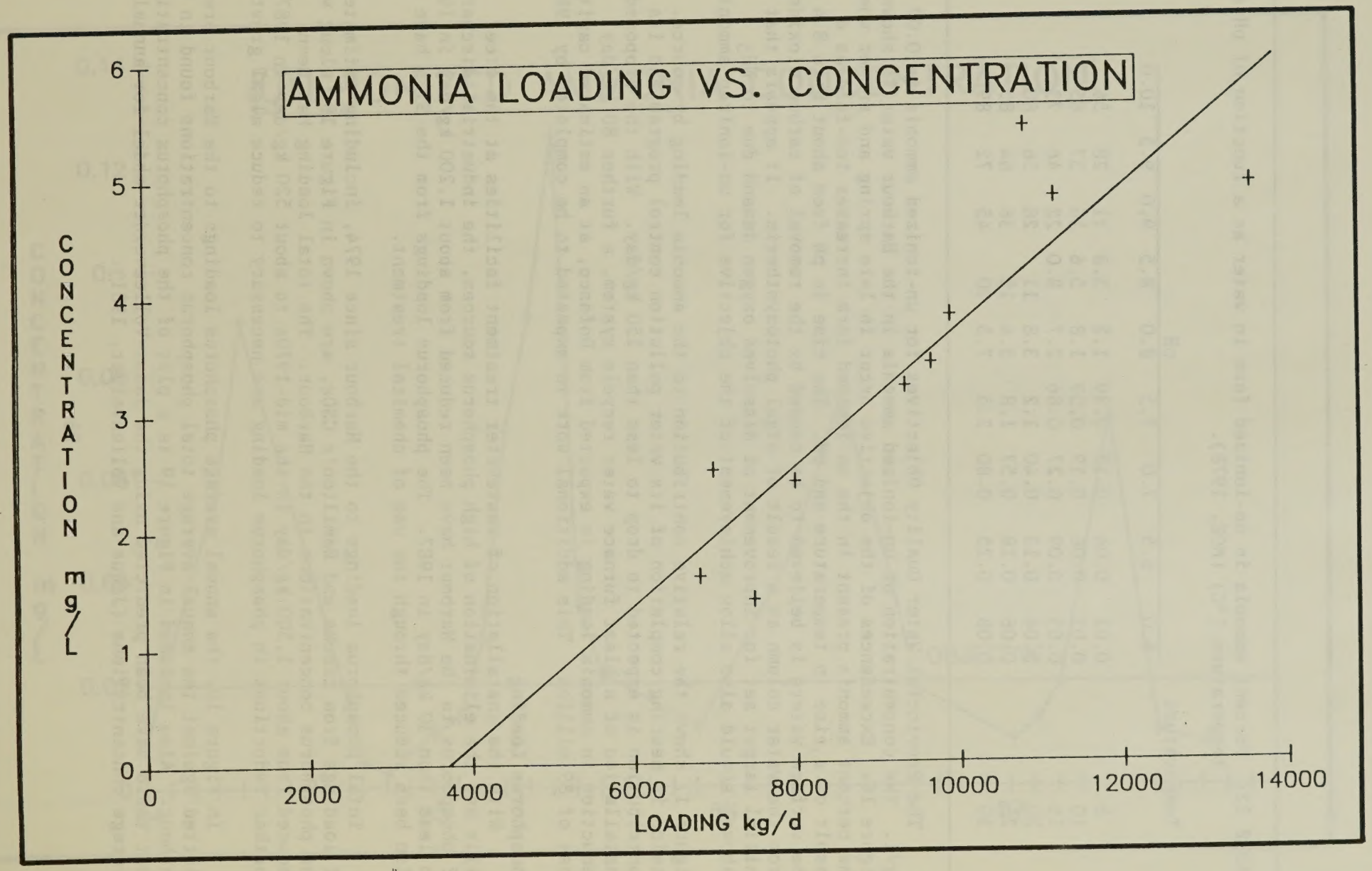


TABLE 22: Percent ammonia in un-ionized form in water as a function of pH and temperature (°C) (MOE, 1978).

Temperature	pH								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	0.01	0.04	0.13	0.39	1.2	3.8	11	28	56
10	0.02	0.06	0.19	0.59	1.8	5.6	16	37	65
15	0.03	0.09	0.27	0.86	2.7	8.0	22	46	73
20	0.04	0.13	0.40	1.2	3.8	11	28	56	80
25	0.06	0.18	0.57	1.8	5.4	15	36	64	85
30	0.08	0.25	0.80	2.5	7.5	20	45	72	89

The Provincial Water Quality Objectives for un-ionized ammonia is 0.02 mg/l. The concentration of un-ionized ammonia in the Harbour water is shown in Figure 16. Exceedences of the objective occur in late spring and summer when the percent ammonia present in the un-ionized form increases ten-fold as a result of a rise in temperature and pH. The rise in pH from about 8 to 8.4 in the surface waters is believed to be caused by the removal of carbon dioxide from the water column as a result of algal photosynthesis. It appears that the initial target set for improvement of dissolved oxygen demand due to NH_3 (above) should also allow achievement of the objective for un-ionized ammonia.

Figure 17 shows the relative contribution to the ammonia loading by source. Stelco is nearing completion of its water pollution control program and its contribution is expected to drop to less than 150 kg/day. With the proposed installation of a blast furnace water recycle system, a further 80 kg/day reduction in ammonia loading is expected from Dofasco, at an estimated capital cost of $9 million. This additional work is expected to be completed by 1989.

Phosphorus Loading

With the installation of wastewater treatment facilities at the steel mills and the elimination of high phosphorus sources, the industrial discharges of phosphorus to the Harbour have been reduced from about 1,200 kg/day in 1967 to less than 30 kg/day in 1987. The phosphorus loadings from the STPs have also been reduced through the use of chemical treatment.

Total phosphorus loadings to the Harbour since 1974, including estimates of loadings from creeks and Hamilton's CSOs, are shown in Figure 18, along with the phosphorus concentrations in the Harbour. The total loading has been reduced from about 1,500 kg/day in the mid-1970s to about 520 kg/day in 1987. Further reductions in phosphorus loading are necessary to reduce algal growth.

In Figure 19, the annual average phosphorus loadings to the Harbour are plotted against the annual average total phosphorus concentrations found in the Harbour. Also included in Figure 19 is a plot of the phosphorus concentrations that would have been predicted using the Janus-Vollenweider model for annual average concentrations (Janus and Vollenweider, 1981).

Figure 16

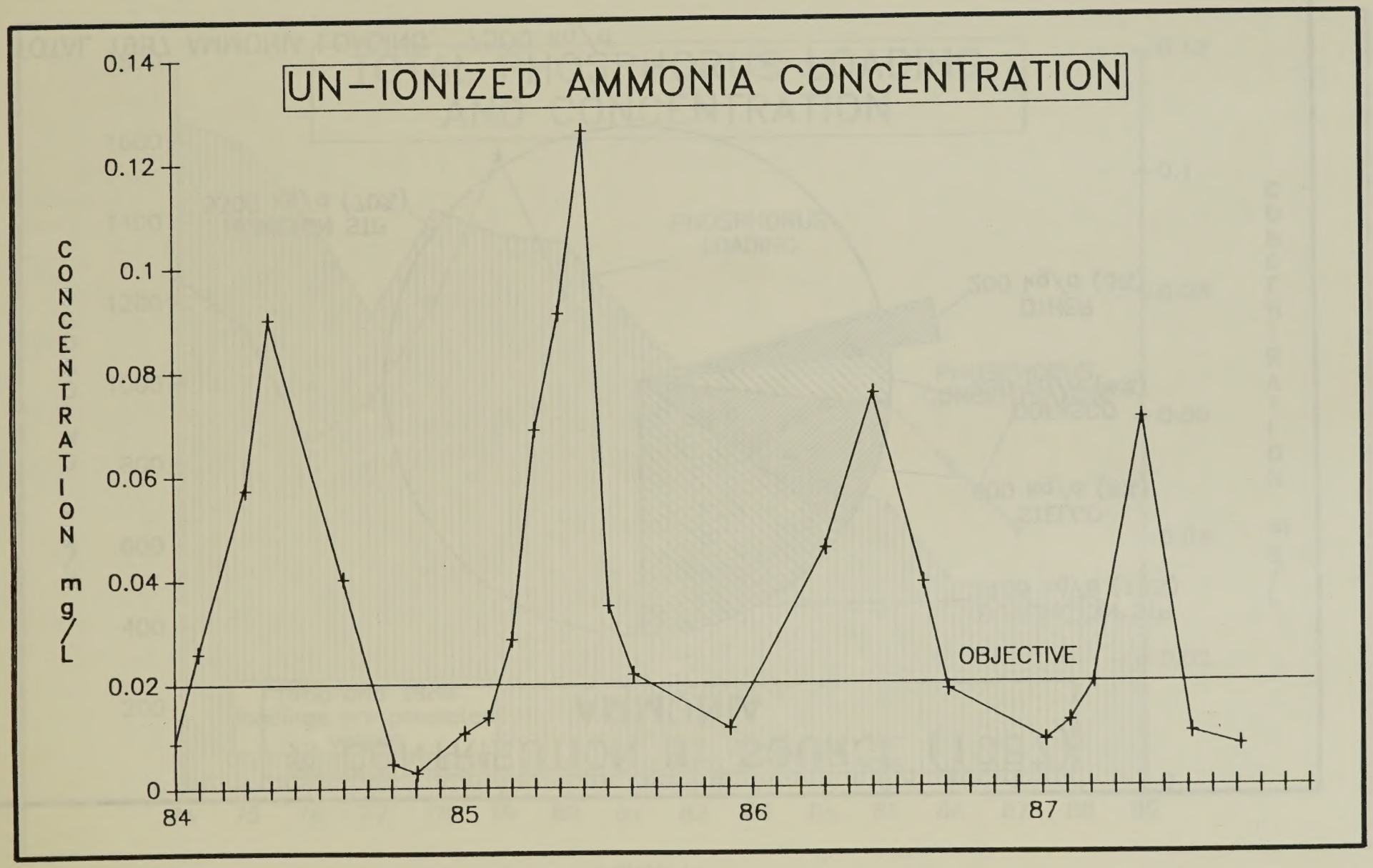

UN-IONIZED AMMONIA CONCENTRATION
CONCENTRATION mg/L
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
84
85
86
87
OBJECTIVE

Figure 17

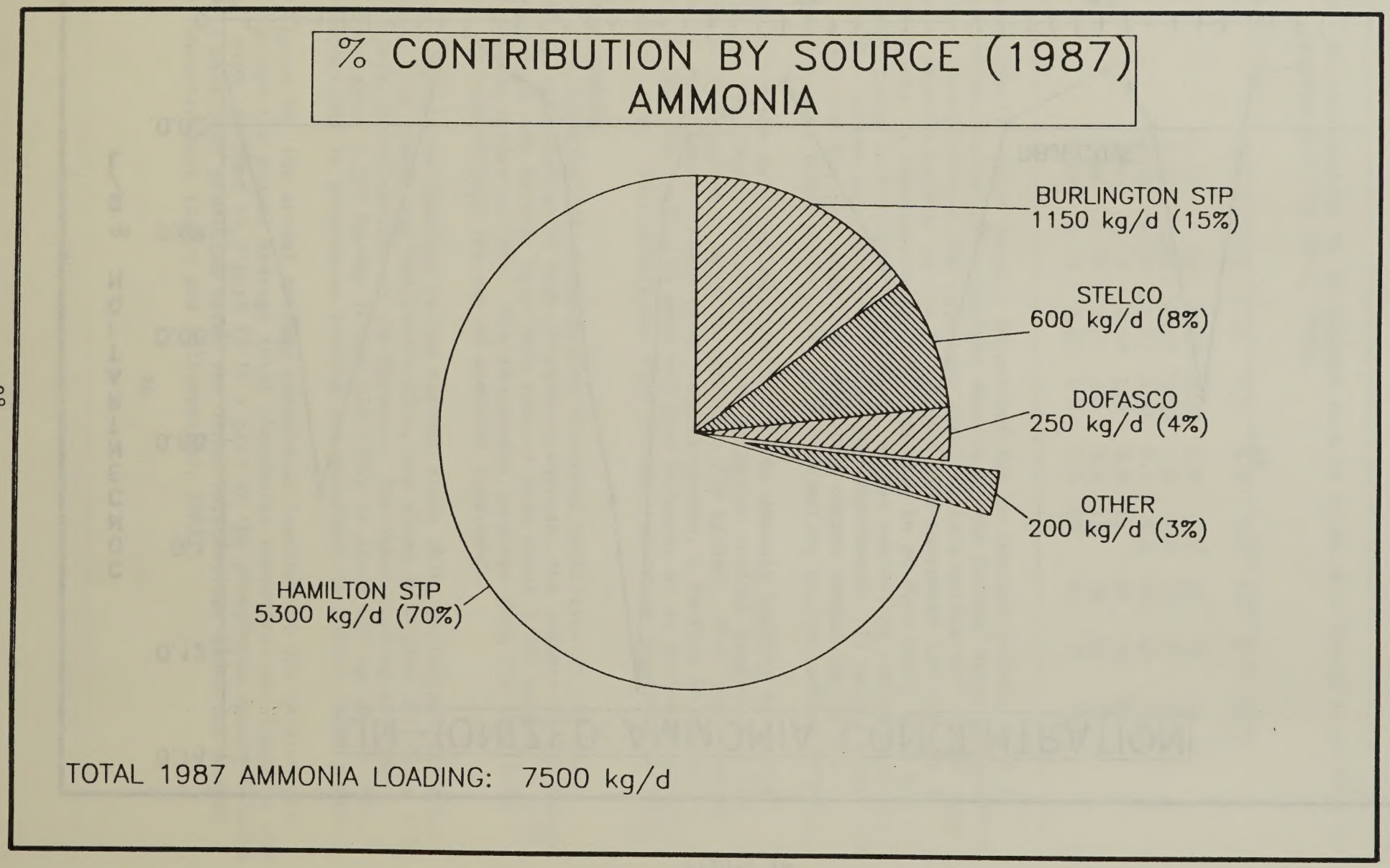

% CONTRIBUTION BY SOURCE (1987)
AMMONIA
BURLINGTON STP
1150 kg/d (15%)
STELCO
600 kg/d (8%)
DOFASCO
250 kg/d (4%)
OTHER
200 kg/d (3%)
HAMILTON STP
5300 kg/d (70%)
TOTAL 1987 AMMONIA LOADING: 7500 kg/d

Figure 18

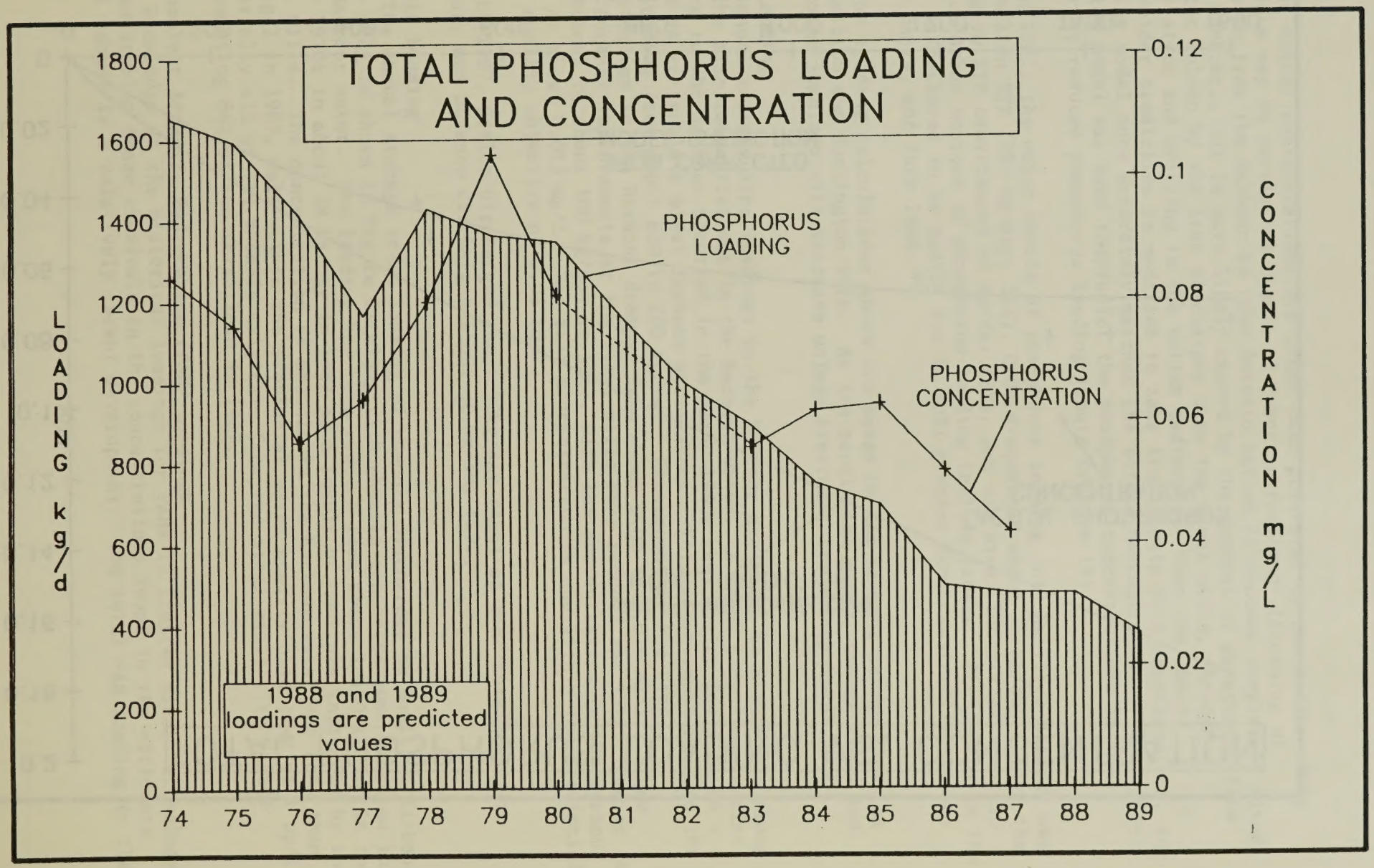
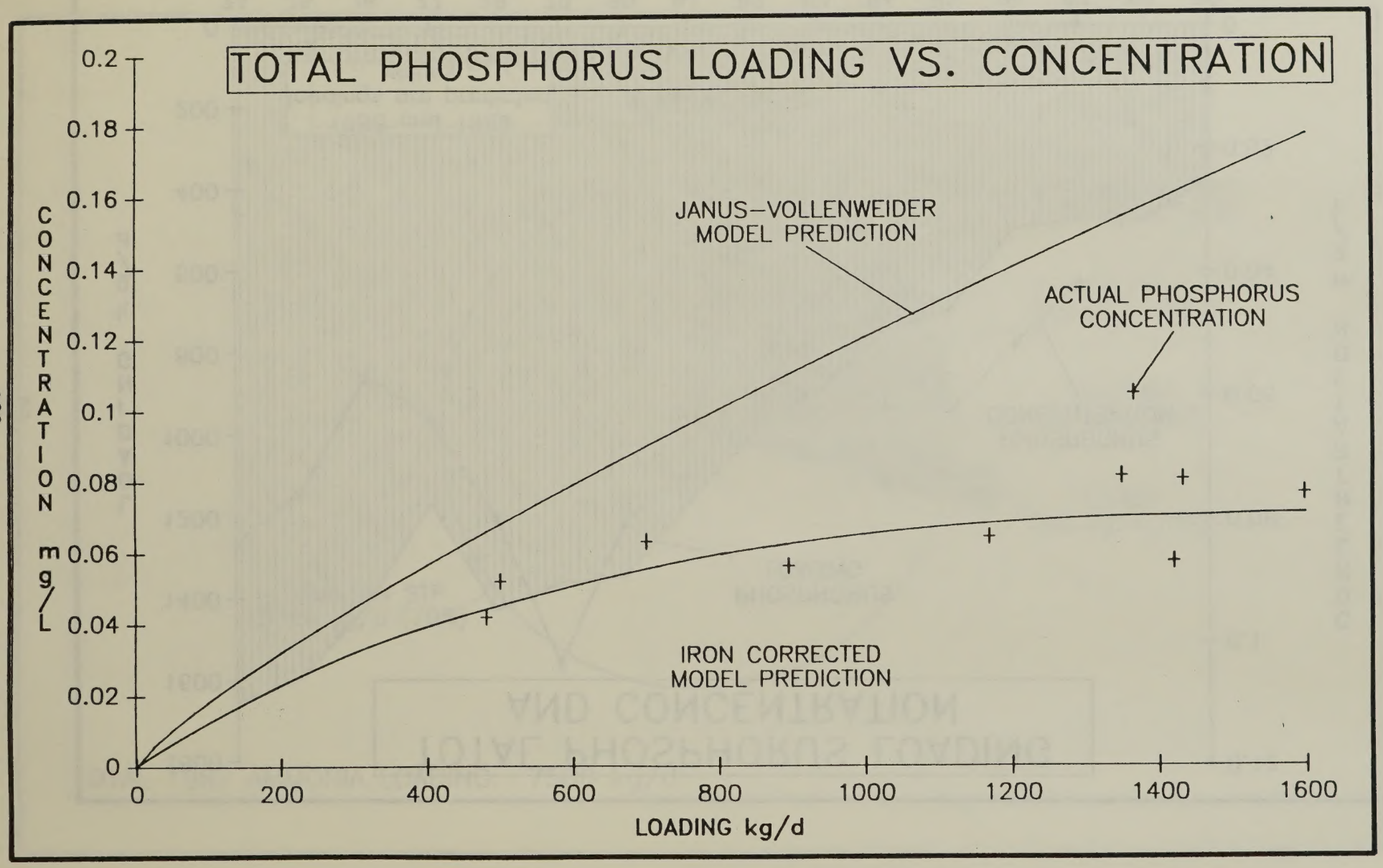

TOTAL PHOSPHORUS LOADING AND CONCENTRATION
LOADING kg/d
CONCENTRATION mg/L
PHOSPHORUS LOADING
PHOSPHORUS CONCENTRATION
1988 and 1989 loadings are predicted values
1800
1600
1400
1200
1000
800
600
400
200
0
0.12
0.1
0.08
0.06
0.04
0.02
0
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89

Figure 19


TOTAL PHOSPHORUS LOADING VS. CONCENTRATION
CONCENTRATION mg/L
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
1200
1400
1600
LOADING kg/d
JANUS–VOLLENWEIDER MODEL PREDICTION
ACTUAL PHOSPHORUS CONCENTRATION
IRON CORRECTED MODEL PREDICTION

The actual concentrations are lower than predicted by the model. This difference may be partly the result of "short circuiting" (flushing of phosphorus from the Harbour to Lake Ontario before it becomes completely mixed in the Harbour), but is more likely caused by the removal of phosphorus from the water column by the iron discharges from the steel mills, through precipitation and settling to the bottom sediments. When the Janus-Vollenweider prediction is modified to take iron inputs into consideration, the resulting model more accurately matches the actual concentrations. The iron-corrected model was used to predict the phosphorus concentrations in the Harbour at reduced phosphorus loading inputs (Figure 19).

In 1987, the major source of phosphorus loading into Hamilton Harbour was the Hamilton STP (290 kg/day, 56%). CSOs discharged about 78 kg/day (16%), the Burlington STP contributed 40 kg/day (8%), and the steel industries about 10 kg/day. Other sources of phosphorus loading include creeks. Phosphorus in the creeks is believed to be mostly due to soil erosion from construction sites, stream banks, and farm land.

The loading calculations above are based on the present sewage flows at the Hamilton and Burlington STPs. As the population grows, sewage flows and phosphorus loadings will increase unless treatment technology keeps pace.

Zinc Loading

Annual average zinc loadings to the Harbour are shown in Figure 20, along with the zinc concentrations in the Harbour water. A major reduction in zinc loading to the Harbour occurred in the early 1980s when Stelco installated a system to recirculate blast furnace wastewaters. This improvement reduced the zinc loading from about 800 to 200 kg/day. Consequently, the zinc concentration in the Harbour dropped from about 0.05 to 0.018 mg/l. Since then, further improvements at the steel mills have reduced the total loading to the Harbour to about 100 kg/day in 1987, with the concentration in the Harbour water at about 0.013 mg/l. The zinc concentration is now within the Provincial water quality objective of 0.03 mg/l.

In 1987, Stelco discharged about 50kg/day (48%) of zinc into Hamilton Harbour, and Dofasco discharged about 30 kg/day (29%).

Phenols Loading

The annual average total loading of phenols discharged to Hamilton Harbour since 1974 is shown in Figure 21 along with phenols concentrations measured in the Harbour water. The loading has been reduced from about 2,600 kg/day in the early 1970s to about 38 kg/day in 1987 as a result of controls installed by the steel mills. The concentration of phenols in the Harbour water was less than 0.4 ug/l in 1987, well within the Provincial water quality objective of 1 ug/l. Essentially all of the phenols originate from the steel mills with Stelco representing 84% of the total load in 1987.

Polynuclear Aromatic Hydrocarbon (PAH) Loadings

Knowledge of the historical loadings for PAHs is limited since technology for monitoring these chemicals in the concentrations found in the effluents (ng/l range) is a relatively recent development. The total PAH loading to the

Figure 20

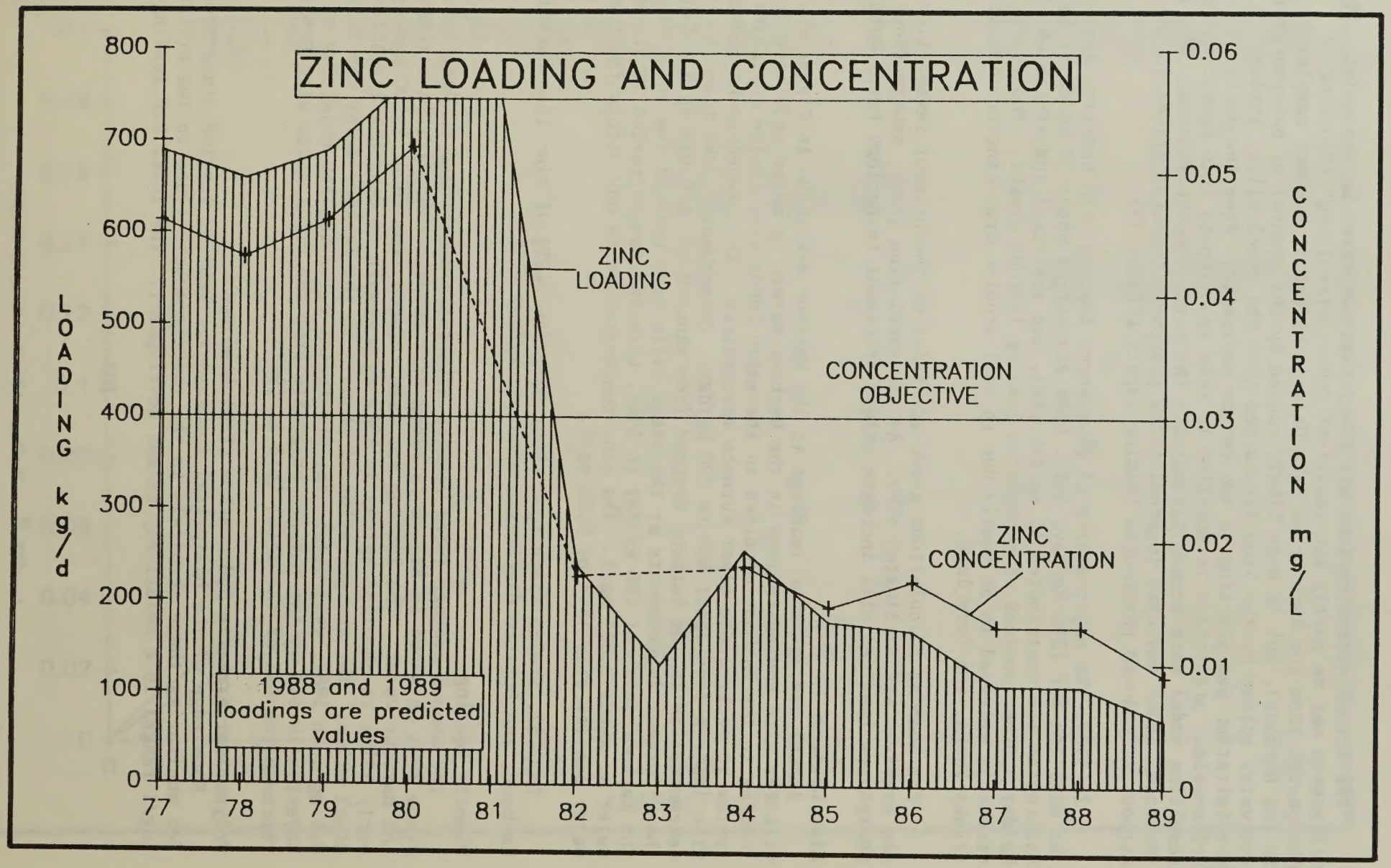
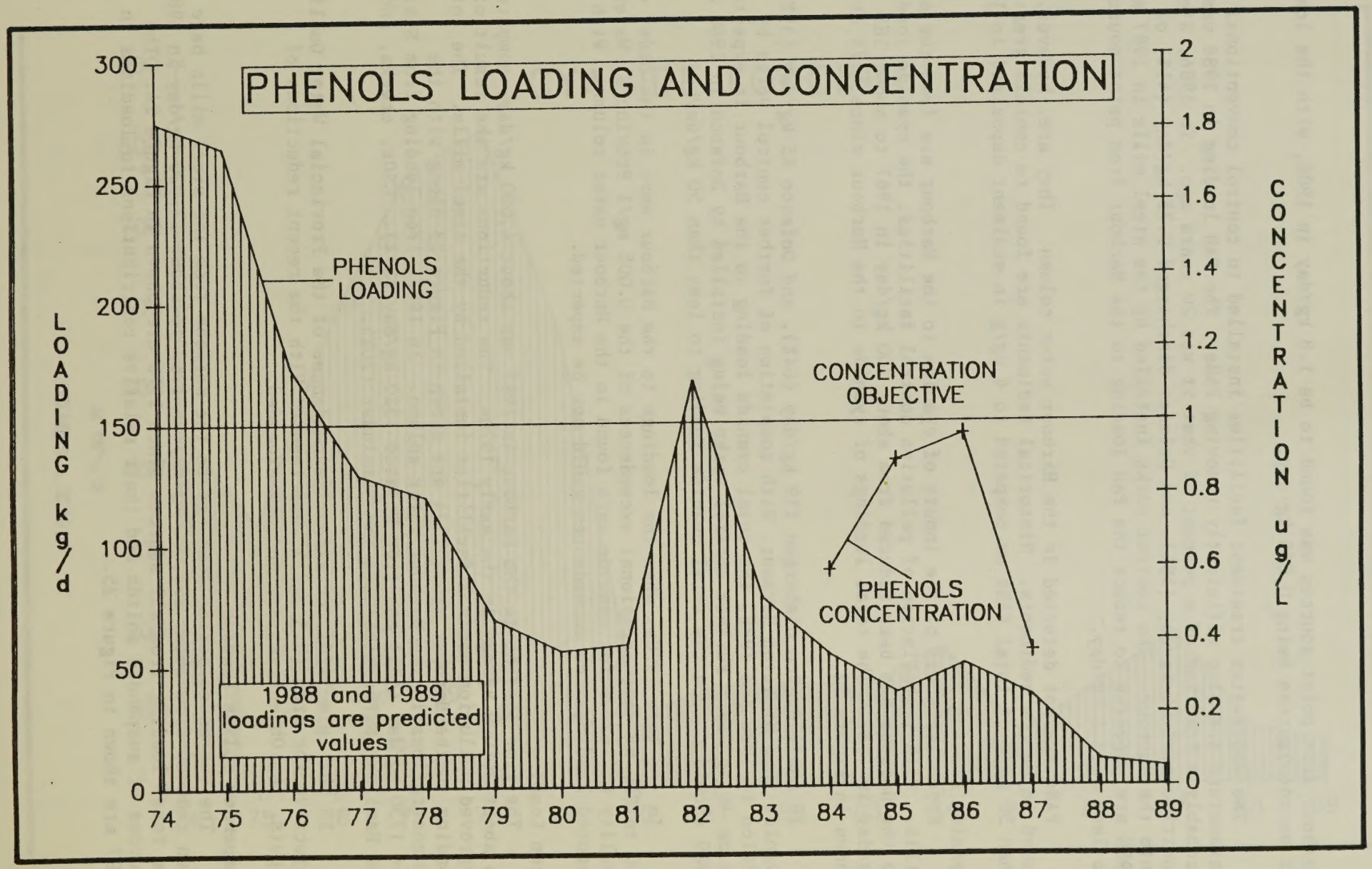

ZINC LOADING AND CONCENTRATION
LOADING kg/d
CONCENTRATION mg/L
800
700
600
500
400
300
200
100
0
0.06
0.05
0.04
0.03
0.02
0.01
0
77
78
79
80
81
82
83
84
85
86
87
88
89
ZINC LOADING
CONCENTRATION OBJECTIVE
ZINC CONCENTRATION
1988 and 1989 loadings are predicted values

Figure 21


PHENOLS LOADING AND CONCENTRATION
LOADING kg/d
CONCENTRATION ug/L
PHENOLS LOADING
CONCENTRATION OBJECTIVE
PHENOLS CONCENTRATION
1988 and 1989 loadings are predicted values
300
250
200
150
100
50
0
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89

Harbour from point sources was found to be 1.8 kg/day in 1986, with the loading of benzo(a)pyrene being 0.068 kg/day.

The wastewater treatment facilities installed to control conventional parameters are also efficiently removing PAHs. The PAH loading in 1986 was probably a fraction of a percent of what it was 20 years ago. In 1986, Stelco contributed 1.05 kg/day (58%), and Dofasco discharged 0.75 kg/day (41%) of PAHs into the Harbour. The control works installed by the steel mills in 1987 and 1988 are expected to reduce the PAH loading to the Harbour from point sources to less than 1 kg/day.

PAHs are not detected in the Harbour water column. They are, however, found in bottom sediments. Historical sediments are found to contain greater than 50 µg/g of total PAHs as compared to 4 µg/g in sediment deposited in 1987.

Cyanide Loading

Essentially all of the inputs of cyanide to the Harbour are from the steel mills. With installation of pollution control facilities, the cyanide loading to the Harbour has been reduced from about 700 kg/day in 1967 to about 185 kg/day in 1987. The total loadings of cyanide to the Harbour since 1974 are shown in Figure 22.

In 1987, Stelco disharged 119 kg/day (64%), and Dofasco 65 kg/day (35%) of cyanide into Hamilton Harbour. With completion of further control works by Stelco in 1987 and 1988, the total cyanide loading to the Harbour is expected to be 70 kg/day. Further control works being installed by Dofasco in 1988 and 1989 should reduce the total cyanide loading to less than 50 kg/day.

In the late 1970s, when the loadings to the Harbour were in the order of 700 to 800 kg/day, occasional exceedences of the 0.005 mg/l Provincial Water Quality Objective for cyanide were found in the Harbour water column. With the reduced loadings, no exceedences would now be expected.

Iron Loading

The iron loading to the Harbour in 1987 was about 4,000 kg/day, compared to about 20,000 kg/day in the early 1970s. The reductions are the result of improved pollution control facilities installed by the steel mills. The total loading to the Harbour since 1974 are shown in Figure 23 along with the concentrations in the Harbour water column. In 1987, iron loading from Stelco was 1750 kg/day (43%) and from Dofasco 1520 kg/day (37%). CSOs, creeks, and the Hamilton STP contributed the remainder (20%).

In the late 1970s, occasional exceedences of the Provincial Water Quality Objective for iron (0.3 mg/l) were found. With the recent reductions of inputs, the Objectives are not now exceeded.

Suspended Solids Loading

The suspended solids loadings to the Harbour from the steel mills have been reduced from about 150,000 kg/day in 1967 to about 12,000 kg/day in 1987. The total loading from all sources since 1978 are shown in Figure 24. The sources of suspended solids and their relative contributions to loadings in 1987 are shown in Figure 25.

Figure 22

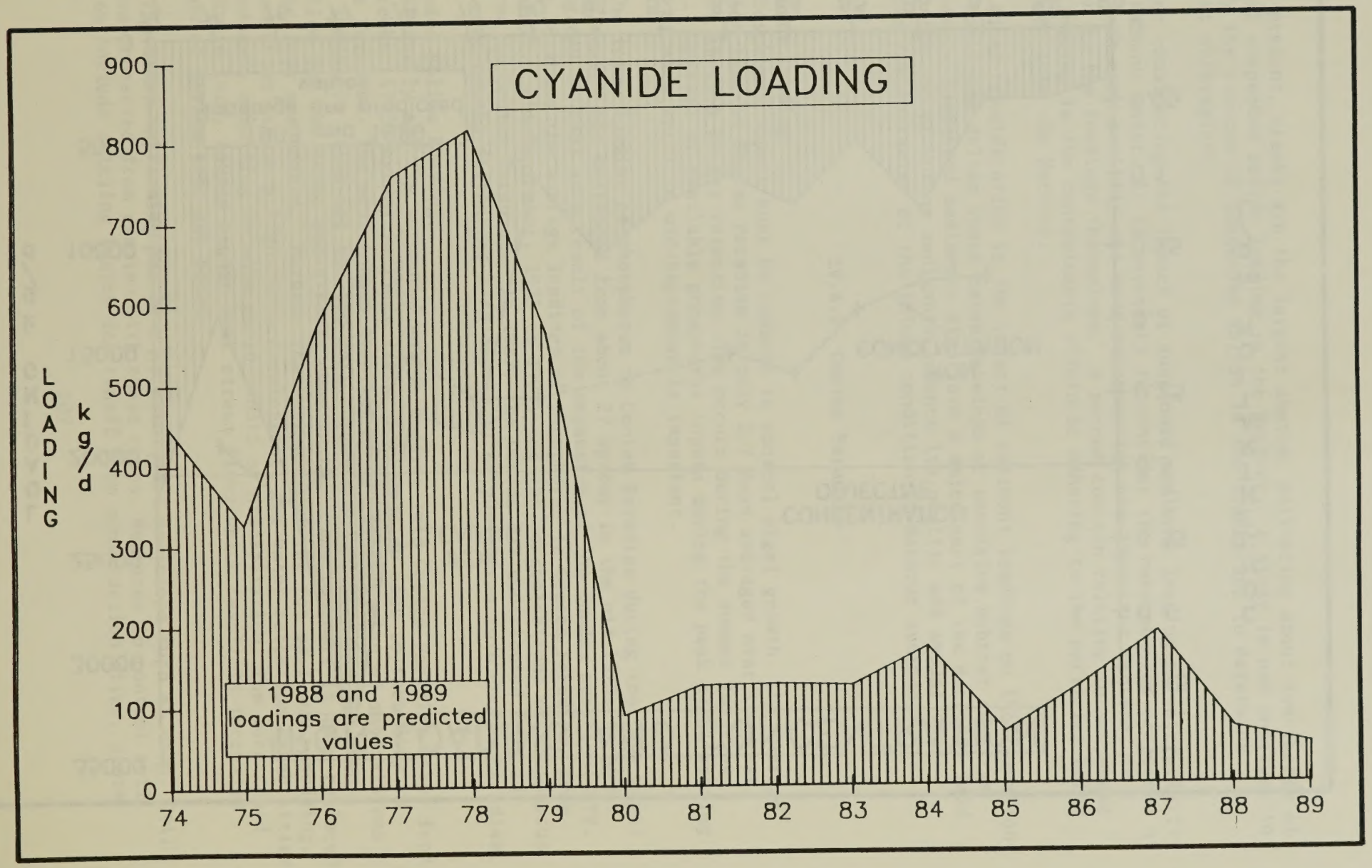
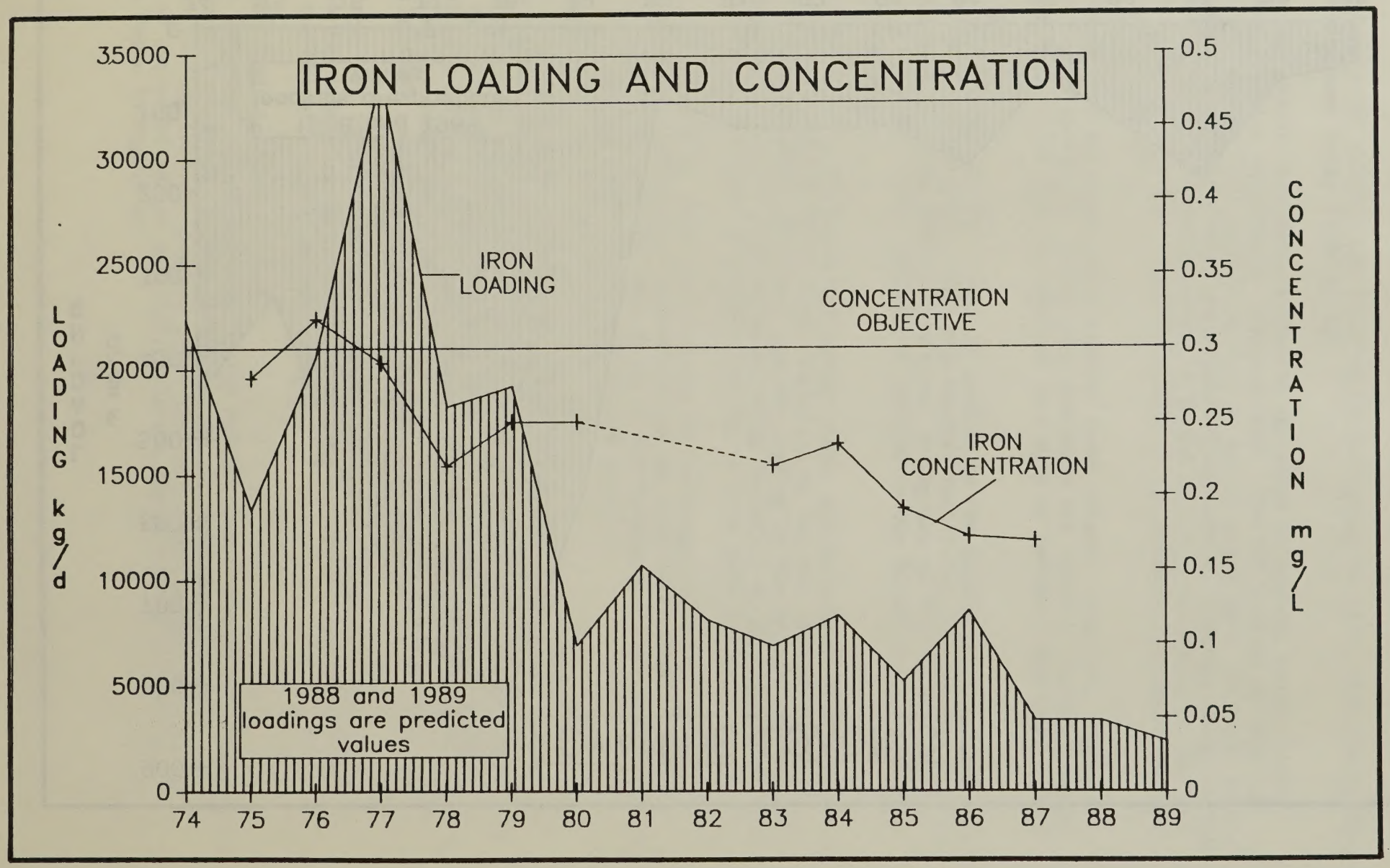

CYANIDE LOADING
LOADING kg/d
900
800
700
600
500
400
300
200
100
0
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
1988 and 1989 loadings are predicted values

Figure 23


IRON LOADING AND CONCENTRATION
LOADING kg/d
CONCENTRATION mg/L
35000
30000
25000
20000
15000
10000
5000
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
IRON LOADING
CONCENTRATION OBJECTIVE
IRON CONCENTRATION
1988 and 1989 loadings are predicted values

At present, creeks are the largest source, delivering about two-thirds of the total suspended solids loading to the Harbour. A study is now underway to identify the sources of suspended solids in the creeks and to determine abatement strategies.

When considering the impact of suspended sediment loading on water clarity in the Harbour water, it is necessary to consider the resuspension processes at work. Both carp activity and wave resuspension are important factors, in addition to the loadings themselves. A second concern relating to suspended solids loading is the contaminants within or adhering to the particles being discharged into the Harbour.

A final consideration is the impact of sediment loadings on the formation of mud banks and deltas where marsh develops or sensitive habitat requires maintenance. Suspended sediments also form a major part of the material laid down on the top of bottom sediments. Hence its quality and amount will determine the character of the future condition of Harbour sediments.

IV.4.2 Cootes Paradise

Phosphorus Loading

Phosphorus inputs must be reduced to control algal growth. The average retention time in Cootes Paradise is only 2.7 days averaged over the year. However, about a 20-day retention time occurs during the summer low flow period. Control of available phosphorus inputs during the peak algal growing season of mid- April to mid-September is important.

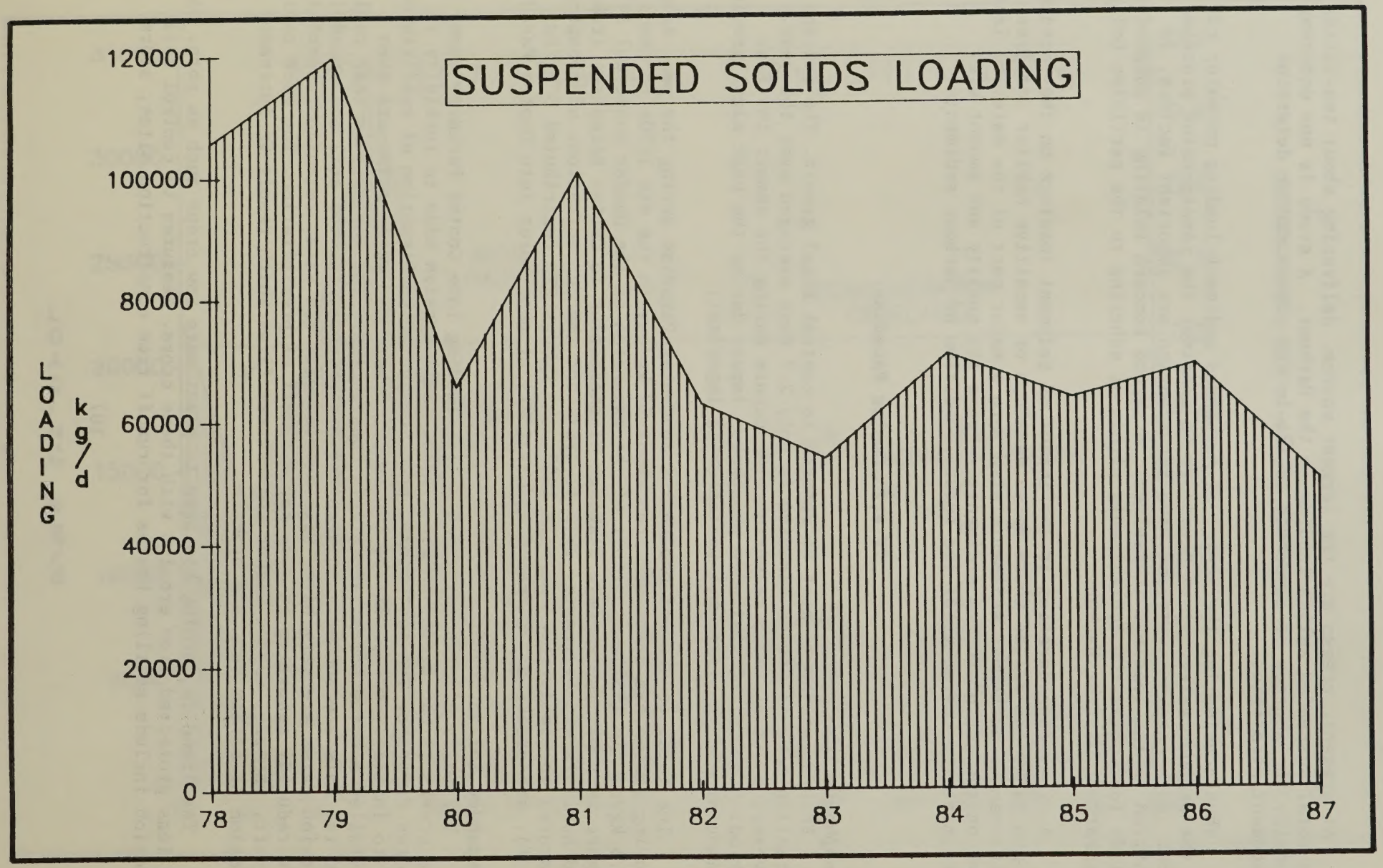
The total loading of phosphorus to Cootes Paradise during the peak algal growing season has decreased from about 27 kg/day in the mid 1970s to about 10.6 kg/day in 1987 as a result of the expansion of the Dundas municipal STP. Figure 26 shows the average loadings of phosphorus to Cootes Paradise, from mid-April to mid-September, 1975 to 1987, and the concentrations of phosphorus measured in Cootes Paradise. In 1987, the Dundas STP contributed 6 kg/day (53%), and creeks discharged 3 kg/day (32%) of phosphorus into Cootes Paradise.

Suspended Solids Loadings

Virtually all the suspended solids loading into Cootes Paradise comes from the creeks (47050 kg/day in 1987, 99%). Soil erosion adds to turbidity in Cootes Paradise. The most common practice in the construction of subdivisions is to initially strip off the top soil. Sewers and water mains are then installed and the homes and streets constructed. The top soil is then replaced and the lots are sodded. Between the stripping of the top soil and resodding, erosion rates are very high. With development, the water retention capabilities are reduced, resulting in more rapid runoff of precipitation. The more rapid runoff, in turn, causes higher peak stream flows which result in increased erosion of stream beds and banks.

The trend in farming has been to plant more row crops such as corn. Soil is less protected from erosion with these crops. Measures to control soil erosion include settling basins for runoff from construction sites, storm

Figure 24


SUSPENDED SOLIDS LOADING
LOADING kg/d
120000
100000
80000
60000
40000
20000
0
78
79
80
81
82
83
84
85
86
87

retention basins to reduce peak storm flows, installing rip rap on creek beds and banks susceptible to erosion, and modifying farm practices to minimize soil loss. The study underway to identify sources of suspended solids and abatement measures to reduce loadings of suspended solids by way of creeks should be completed in 1989.

IV.5 Tabular Summary of Loadings

The preceeding sections have described the trends and details of loading estimates. It was pointed out that current remedial programs (see Appendix E) were substantially lowering many of the contaminant loadings, and that several of the more diffuse loadings (creeks and CSOs), or intermittant loadings due to storms, have not been adequately sampled within a consistent time frame to provide the best current mass balance for the Harbour.

However, to guide decisions on the most effective strategy to follow in reducing loadings, it is useful to have a compilation of the best available information. This is shown in Table 23 (page 112). This table should be updated at regular intervals as new information becomes available.

TABLE 23: Contaminant loadings by source to Hamilton Harbour.

	POINT SOURCES				NON-POINT SOURCES	
	Municipal STPs		Industrial		Storm sewers,	Atmospheric
	Ham.	Burl.	Stelco	Dofasco	Creeks, CSOs	
Flow (1000 cubic metres/day)	307	71	1057	655	302	53
Conventional Contaminant (kg/d)						
T.NH_3-N	5300	1150	600	250	200	17
T.Phos.	290	40		9	185	1
Sus.Sol.	3750	500	8200	4100	2200	
Phenol	2		31	4	2	
Cyanide			119	64	1	
Metal Contaminants (kg/d)						
Arsenic	<0.4	0.2	1.0	1.0		
Cadmium	<0.1	0.1	Tr	0.2		0.1
Chromium	3.9	0.5	19.3	0.2		
Copper	4.1	1.1	1.1	2.7		0.2
Iron	230	64	1750	1520	800	4.4
Manganese				2.3		
Nickel	8.5	0.8	Tr			0.2
Lead	1.5	0.4	12.1	9.1		0.9
Selenium	<0.4	<0.1	Tr	0.8		
Zinc	16	1.4	50	30	9	3.5
Organic Contaminants (kg/d)						
Oil,Grease			4579	55		
PCBs	0.04	0.001	ND	ND		0.007
BHC						0.002
y-BHC						0.011
DDT	0.004	<0.0002				0.0004
Dieldrin	ND	<0.0002				0.0004
Endosulfan						0.006
HCB	0.004	0.003				0.001
Mirex	0.005	0.002				
Chlordane	0.0001	0.0005				
Pesticides	0.02	0.007				
Volatiles	ND	ND	0.08	0.55		
PAHs	0.02	ND	1.05	0.76		0.116

Data extracted from: MOE Datafiles, 1986, 1987; MOE, 1987b, d; Kuntz, 1980; IJC 1980; Hamilton Harbour Study, 1977; Snodgrass, 1981.

V SUMMARY OF ISSUES AND CONCERNS

For the present and future use of Hamilton Harbour, concentrations of pollutants are to be brought below the levels set out in the Provincial Water Quality Objectives. In accordance with the Great Lakes Water Quality Agreement, the virtual elimination of the discharge of persistent toxic substances is also required. In addition to water quality and sediment contamination problems, habitat is also a limiting factor for populations of fish and wildlife in the Harbour.

For Cootes Paradise, more stringent objectives have been established by the Royal Botanical Gardens, which owns the area. The goal is to ensure that plant and animal life will survive and thrive in all parts of Cootes Paradise; and that, as a wildlife sanctuary, Cootes Paradise will be a high quality habitat complex for waterfowl and other marsh-dependent wildlife.

V.1 Eutrophication

In early spring, the Harbour water is saturated with dissolved oxygen, which rapidly declines to 80% saturation in the epilimnion and only 10-20% saturation in the hypolimnion in the summer. In the hypolimnion, the dissolved oxygen fluctuates widely, due to cold oxygen-rich Lake Ontario water entering via the Burlington Ship Canal. If this inflow did not occur, the anoxia would be even more severe.

This aspect of eutrophication has several causes. Large amounts of ammonia and phosphates enter the Harbour from the sewage treatment plants (STPs), creeks and combined sewer overflows (CSOs). The ammonia is nitrified to nitrates by bacteria, a process that requires about 40% of the total oxygen demand in the water column. The nitrates and phosphates are utilized by algae, producing an algal bloom. The algae die and decay, utilizing another 40% of the total oxygen demand. Oxygen demand at the sediment/water interface, from the oxidation of methane and the production of nitrogen, can consume a further 20% of the oxygen. The hypolimnion is therefore virtually anoxic during the summer, and unable to support a coldwater fishery.

The algae themselves present an aesthetic problem as they reduce water clarity and present an unpleasant nuisance growth that fouls beaches and rocks. Phosphorus control is the answer to excessive algal growth.

Generally speaking, the whole Harbour is affected by phosphorus loadings. However, the circulation in the Harbour is such that small, local phosphorus sources have an impact out of proportion to their contribution to the overall loading of the Harbour. These sources affect sensitive habitat in the shallower waters in the embayments and marshy areas at the west end of the Harbour and in Cootes Paradise.

Overall, preliminary loading targets of 3600 kg/day of ammonia and 200 kg/day of total phosphorus for the Harbour are deemed necessary to correct the problem of anoxia, although this will need careful review. Special attention will have to be given to phosphorus loadings in Cootes Paradise and to the western half of the Harbour to improve the algae problems in those areas.

Unionized ammonia itself exceeds the objective over 15 to 25% of the south-east and eastern parts of the Harbour in late winter and early spring. These levels may be acutely toxic to fish. The ammonia loading reductions will improve this situation as well as the anoxia, although loading targets may have to be even lower to meet this water quality criterion.

V.2 Water Clarity

Water clarity affects light penetration to the bottom of littoral areas where submerged macrophytes could grow, thereby affecting the abundance of habitat necessary for certain species of fish. Suspended sediments are the major contributors to poor water clarity in Cootes Paradise and near the mouths of the creeks after rainfalls. In the central areas of the Harbour, the phytoplankton is the major obstacle to improved water clarity. Water clarity is also limited by the presence of dissolved organic substances that impart colour to the water. The origin of this organic matter has not yet been adequately defined, although much of it may arise in the natural waters from the drainage basin.

To improve water clarity, phosphorus loading needs to be reduced to the target noted above, and suspended solids loadings should be reduced by 50%. A better understanding of suspended sediment loads from creeks, from bank erosion below the escarpment, from the high yield rural areas, and especially from urban watersheds is essential. Carp activity is also a major cause of water clarity problems in shallow areas.

V.3 Heavy Metals

The major heavy metals in the Harbour water are iron, zinc, copper, nickel, chromium, lead, and cadmium. The concentrations of these metals in the water column now exceed the Provincial Water Quality Objectives at the mid-Harbour monitoring stations no more than 9% of the time for iron, 3% for zinc, and less than 1% for the more toxic metals. Only ten years ago exceedences were much more frequent. Most of the heavy metals are discharged by the steel industries.

V.4 Organic Pollutants

Organic pollutants include polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), phenols, and pesticides (Mirex, DDT, Diazinon). PAHs are discharged mainly from the steel industries, and the PCBs and pesticides are found in rain, creeks, and the discharges from STPs. PAHs are rarely found in the water except bound to colloidal particles, but are present in the sediments, particularly the "historical" sediments.

PCBs in the water column are not well surveyed. This situation requires more thorough investigation in conjunction with analyses of sediments, rainfall, and biota to ensure that all possible remedial actions have been taken to eliminate local sources.

V.5 Hamilton Harbour-Lake Ontario Relationship

Much of the dissolved heavy metals and organic pollutants leave the Harbour as the Harbour is flushed by Lake Ontario water entering through the Burlington Ship Canal. It has been calculated that water flowing into the Harbour from creeks and STPs would be retained for about 500 days without the large, deep ship canal; the flushing action reduces the retention time to an average of about 90 days. The Lake water which enters in summer is usually colder, and hence more dense than the Harbour water; consequently it tends to flow underneath the more contaminated surface water once it has passed through the 10m deep Canal into the Harbour. This is a major factor in replenishing the oxygen in the summer hypolimnion.

The general flushing action that results from this exchange of water has the effect of diluting Harbour water with better quality water from the Lake. This exchange takes place close to the major STP and industry discharge locations (in the east end of the Harbour), and thus facilitates the discharge of the more contaminated water of the Harbour to the Lake, before it can mix with the whole Harbour.

On the other hand, all waste from industry and municipal sewage treatment plants, along with urban and rural runoff in the watershed are discharged into the Harbour. None is discharged directly to Lake Ontario. This waste puts extreme stress on the Harbour's aquatic ecosystem and assimilation capacity.

V.6 Contaminated Sediments

Since the late 1970s and early 1980s, when treatment of sewage and industrial waste was improved, the concentrations of priority pollutants in the Harbour water and recently deposited sediments have decreased dramatically. However, in earlier years, large quantities of heavy metals and organics were discharged. Some of those loadings still remain in the historic sediments, buried beneath recent deposits.

Bioassays have indicated a wide variability in toxicity of the sediments. Certain areas of the Harbour are clearly indicated as urgent sites for remediation because of toxic sediments. More generally, the sediments in Hamilton Harbour exceed acceptable limits for open water disposal of dredgeate under Provincial Guidelines. Contaminated sediment, if it is moved, must be placed in a confined disposal facility. Current facilities are designed only for dredgeate from navigational dredging, and are only adequate to the year 2000. Thus, further disposal procedures will have to be developed, both for handling navigational dredgeate beyond 2000 and for dredgeate resulting from dredging undertaken to remediate the more contaminated areas.

In the hypolimnion, anoxic conditions facilitate the release of manganese and iron, rendering these elements more bioavailable. Other metals may also be released. Biomagnification of contaminants by benthic organisms is of concern due to possible transmission to predator species and subsequent accumulation through the food web.

The optimal method for dealing with contaminated sediments in areas other

than those normally dredged for navigation purposes is not known. Dredging large parts of the Harbour is probably impractical, from the point of view of siting for disposal. Dredging on a large scale is also likely to have a severe environmental impact. Some small areas of the most contaminated sediments might be dredged under suitable controls for both the dredging operation and the disposal of the dredgeate. As for other methods, the issue is the choice of chemical or physical treatments (or natural burial) that might be effective. Whatever the case, it is essential that we understand first whether the current loadings of the contaminants causing the sediments to be toxic have been reduced sufficiently to prevent re-occurrence of the problem. That information is being further developed.

V.7 Stresses on Fish and Wildlife

Historical documents reveal that Hamilton Harbour and Cootes Paradise supported abundant wildlife. A commercial fishery thrived, a commercial fur harvest existed, and waterfowl nested in the extensive marshlands in Cootes Paradise and along the south shore of Hamilton Harbour. In the fall, the area became a staging ground for millions of migrating birds.

As industrial and urban development proceeded, the Harbour marshlands were either filled for industrial land or dredged for shipping. Urbanization of the drainage basin has also resulted in the loss of the Cootes Paradise marsh. The discharging of excessive nutrients and the resultant oxygen depletion of the hypolimnion, along with overfishing and the introduction of exotic species, destroyed the coldwater fishery. The fish population changed slowly from large, long-lived predator species to the smaller, short-lived, pollution-tolerant foraging species characteristic of eutrophic environments.

Ammonia is still present in sufficiently high concentrations to affect the fish and benthic populations as a toxic contaminant. The concern is documented in section V.4.

Fishing stress on the Harbour, while light at the present, could be a concern in the future. The one exception is the carp, which could be selectively removed in order to alleviate the stress which it puts on habitat and water clarity.

While there appears to be adequate adult fish habitat for warm-water species, habitat for spawning and for juvenile stages of some key species is lacking. The areas with the most potential for habitat redevelopment are Cootes Paradise, the western end and the north shore of the Harbour, and the estuary of Grindstone Creek.

Neoplasms and other lesions have been reported on several species of fish. It is uncertain whether their origins are chemical or biological. Carcinogens are suspected, although standards for acceptable frequencies of lesions, and the exact cause of lesions, have not been established. Thus it is difficult to identify specific remedies or acceptable levels of their incidences. There is generally a higher prevalence of lesions on fish from urban areas such as Lake Ontario and Hamilton Harbour than on fish from Lake Huron or Manitoulin Island, but comparative data are not adequate.

PCBs and other organochlorine levels were higher in snapping turtle eggs from Hamilton Harbour than from nine other sites in Southern Ontario. Hatching deaths were also greatest at Hamilton Harbour and one other site, but deformities were highest elsewhere. Turtles in Hamilton Harbour may also be subject to contaminants in the Lake, because the fish they eat migrate between the Lake and the Harbour.

Colonial bird populations are in much better shape than in the mid 1970s. The concentration of contaminants in gull eggs, low hatching rates and the incidence of mutants have all declined. Reproductive rates are considered normal at present.

Present concerns are: the heavy metals and toxic organics in the sediments of Windermere Basin and the confined disposal facilities and their impact upon wildlife; and the future development plans which could result in habitat loss in Windermere Basin, the Hydro Islands, and Pier 27 (north end of the existing CDF). In addition, redevelopment of marsh habitat in Cootes Paradise would add considerably to the wildlife potential in the area.

V.8 Other Biota

Algal production and species composition is affected by physical mixing processes and, very recently, possibly by phosphorus concentrations.

Zooplankton populations have not been sampled recently, so conclusions with respect to their species composition are not possible at this time.

Benthos populations have improved in numbers and composition over the last 20 years. Bioassays suggest that they are affected by conditions in the sediment. Current research is trying to determine if mitigation of the benthic habitat can be achieved by improving the oxygen concentration in the summer hypolimnion.

Approximately 90 hectares of submergent vegetation is present in Hamilton Harbour. The number of species is low, but typical of turbid water bodies with a low diversity of habitat types and sediments with low organic content.

V.9 Fish Consumption Advisories

Due to the presence of contaminants in Ontario fish, a "Guide to Eating Ontario Sport Fish" has been published. Five of the 12 species listed for Hamilton Harbour have consumption limitations; one of these species is restricted for all sizes. Consumption limitations arise from the presence of one or more of Mirex, PCBs, and mercury.

Concerns for an edible fishery in Hamilton Harbour must be addressed on a whole lake basis. Many of the non-resident species accumulate contaminants lake-wide, and it is unlikely that reduced loadings in Hamilton Harbour alone will result in elimination of fish consumption advisories.

V.10 Body Contact Sports and Swimming

V.10.1 Bacteria

In the 1930s, the Hamilton Harbour Commission, acting on the advice of the Medical Officer of Health, enacted a by-law prohibiting swimming in the whole Harbour because of fecal contamination of the water. Windsurfing is prohibited for the same reason, and some boating is risky where capsizing might occur. Levels of fecal coliform bacteria (indicators of fecal contamination) vary throughout the Harbour with conditions ranging from suitable for swimming to completely unacceptable. Higher levels of bacteria are found after rain and in areas close to sources.

The sources of fecal coliform bacteria are combined sewer overflows, sewage treatment plant by-passes, sewage treatment plant effluent, runoff from urban (streets) and rural areas (animal sources), illegal sewer hookups, and malfunctioning septic tank systems. The relative importance of these sources has yet to be established for each affected area in the Harbour.

Since the sources of fecal coliform bacteria are widely distributed, no area in the Harbour is completely free of contamination. The least affected areas are along the north shore and at the west end. Given the existing use of the Harbour by recreational boating, open water areas must also be considered. Of course, any strategy which controls bacterial problems in nearshore areas would eliminate offshore problems which arise from the mixing of Harbour waters.

V.10.2 Water Clarity

There is a provincial water clarity criterion for swimming, which the nearshore waters of the Harbour often fail to meet. Reduced water clarity is due to the combined effects of suspended sediment and algae. Sediment material enters the water column from creeks carrying eroded soil, shoreline erosion, bottom sediments stirred up by wave action, and resuspension caused by the feeding activities of carp. The north and east shores of the Harbour are particularly prone to the sediment-related causes. Algal problems causing reduced water quality occur throughout the Harbour.

V.11 Aesthetics

Persistent objectional loadings of oil and grease have been deposited in the deeper parts of the Harbour, but are not present now in the shallower areas. Oil sheens are observed infrequently. Discharges from urban areas and combined sewer overflows result in periodic occurrences of objectionable turbidity, floating scum, debris, and putrid materials. Combined sewer overflows are the main concern in this regard. Water clarity, discussed above, is also an aesthetic concern.

The aesthetic quality of an area cannot be easily quantified. Hamilton Harbour is important in the life of the Hamilton and Burlington region; it provides jobs as well as recreation and scenery. However, the murkiness of nearshore waters, an unsightly shoreline, noise from highways, and the smells

and haze from industrial operations all detract from enjoyment of the Harbour.

V.11 Community, Agency, Industry, and Citizen Cooperation

The situation in Hamilton Harbour presents a challenging opportunity to demonstrate the willingness and capability of many people to work together to restore more uses for the Harbour and Cootes Paradise. It is customary to emphasize the diversity of interests that have a stake in a place like Hamilton Harbour. Nevertheless, a group of 50 Stakeholders have been drawn together to assist in the development of the Remedial Action Plan. And they have been very active in reviewing the results of the work of the Technical Team, as well as developing their own reports.

As the Plan moves forward, however, there is a need to develop a more viable institutional arrangement to monitor its implementation, and the inevitable changes that will have to accompany such long term plans. This is not just a function of the diversity of political jurisdictions, regulatory powers and mandates, complicated though they are. It is also a matter of achieving an adequate ecosystem approach that ensures that decisions made in the watershed do not now, nor in the future, negate our collective efforts.

In an important sense, the condition of the Harbour and the conditions of the social and economic state of the communities around the Harbour are inextricably linked. In order to sustain development in an environmentally sound way, a broad consultative mechanism needs to be put into place along with adequate means to ensure that decision-making is made accountable for the broader social, economic, and environmental impacts. The Harbour can be a focus for such efforts because it receives all waterborne waste from the watershed, and because much of the critical habitat for fish and wildlife is dependent on land use decisions around the shores.

VI REMEDIAL ACTION PLAN DEVELOPMENT ACTIVITIES

This report addresses the first two information requirements called for in elements (i) and (ii) of Section 4(a) of Annex 2 of the 1987 revised Great Lakes Water Quality Agreement, namely:

(i) A definition and detailed description of the environmental problem in the Area of Concern, including a definition of the beneficial uses that are impaired, the degree of impairment and the geographic extent of such impairment;

(ii) A definition of the causes of the use impairment, including a description of all known sources of pollutants involved and an evaluation of other possible sources;

It must not be thought that this presentation is the sole activity in the development of the Remedial Action Plan (RAP). The basic information in this report was submitted to the Canada-Ontario Agreement Review Board and the Hamilton Harbour Stakeholder Group in March 1988, along with progress reports on the development of offer aspects of the RAP. That material has received considerable public and peer review, which is reflected in this report. The process has not waited upon the completion of this report. The Stakeholders presented their views, goals and principles soon after the initial Information Workshop as is appropriate for the direction of the development of remedial and preventive options. The March 1988 report contained the first set of technical options that it had been possible to assemble to that date, and these have been discussed within agencies, and between the writing team and Stakeholders. Eighteen major reviews of the March 1988 report have been received and considered for the development of this report (the Stage 1 report), and as direction for the development of materials and options for the next stage of our deliberations.

In the complete RAP process, the milestones have been as follows:

VI.1 Hamilton Harbour RAP Development Progress

The first step in developing the RAP was to prepare a technical summary of a number of recent investigations of the Harbour. This was published in August 1985 with general management options. Other technical reports were developed on the impact of the Harbour on western Lake Ontario and on trace contaminants in the Harbour.

Two principal public consultation processes have been employed. One is directed at the general population of the Hamilton-Burlington area. The other involves the principal "Stakeholder" groups, including agencies, organizations, institutions, government bodies, industries and private citizen groups who make use of, wish to make use of, or in some manner have jurisdiction over the use of the Harbour water (See Appendix D). Both sets of activities started in July 1986.

A RAP Team, made up of representatives of the Ontario Ministry of the

Environment (Water Resources Branch and West Central Region Office), Environment Canada (Environmental Protection Regional Office and the National Water Research Institute), Royal Botanical Gardens, Department of Fisheries and Oceans and the Ontario Ministry of Natural Resources, was formed in May 1986. This team has worked closely with the Stakeholders throughout this process. A Team member from the Ontario Ministry for Agriculture and Food was added.

In June 1986, 60 potential stakeholders were interviewed individually to assess their views on the future for the Harbour's water quality. Many of these individuals took part in a workshop July 10 and 11, 1986, where they were presented with the information on the Harbour situation. They met on July 25th to finalize their views on the use goals for the Harbour with accompanying principles and some specific recommendations on the direction of the action plan. The Interim Report of the Stakeholders was released in September 1986.

The Stakeholder group met in December 1986 to audit the first details of the work of the writing team. Subsequent meetings in January and February of 1987 dealt with specific issues and agency responses to the Interim Report. In March 1987, the first progress report of the RAP Team was discussed and recommendations were made to the Team.

Parallel with this activity was a program to involve a wider public through general meetings in July 1986 and February and March 1987. These were information sessions with opportunities for questions to be addressed to the RAP Team. Several formal briefs were also presented. Throughout these consultations, full records have been kept of comments, advice and critiques.

Concurrent with the consultative process, the RAP Team drafted about 85% of those sections of the report dealing with the environmental data base. Specific objectives were prepared for the goals recommended by the stakeholders and several remedial action options were explored to achieve those objectives.

Additional studies were scheduled for 1987 and 1988 to assist in the development of the RAP. Their objectives were: a) detailed surveillance to set the baseline for future improvements and for design of future surveillance; b) further assessment of the contaminated sediments; c) feasibility of new mitigation measures (e.g. ammonia control at the Hamilton sewage treatment plant (STP) and phosphorus treatment for 0.1 mg/l total phosphorus in effluent, etc.); d) identification of fishery rehabilitation requirements; e) detailing the likely impact of various remedial options; and f) development of a cost-benefit analysis of remedial options. Agencies involved include Ontario Ministry of the Environment, Environment Canada, Department of Fisheries and Oceans, Royal Botanical Gardens and Hamilton-Wentworth Region.

No new remedial actions have been initiated as a result of the RAP, although several measures have recently been completed by Stelco Canada and Hamilton-Wentworth Region. There are no outstanding control orders regarding effluent to the Harbour. All STPs are within Ontario MOE guidelines.

VI.2 RAP Timetable

DATE	ACTIVITY
Wastewater Treatment Works Completed or Underway:	
1985	Stelco #2 byproducts final coke oven gas cooling - converted to indirect cooling.
1986	Stelco #1 byproducts interceptor sump effluent - diverted to treatment system.
1984	Dofasco coke oven byproducts cyanide tower - wet oxidation treatment.
1984	Dofasco #1 acid regeneration plant upgrading.
1984	Dofasco upgrading of oil recovery in the Ottawa Street sewer.
1986	Dofasco upgrading of cold mill wastewater treatment.
1985	Hamilton STP upgrading of phosphorus removal to meet the Great Lakes Water Quality Agreement Objective (1 mg/l).
1987	Stelco #1 byproducts final coke oven gas cooling - indirect cooler.
1987	Stelco #2 byproducts interceptor sump effluent - diversion to treatment.
1987	Stelco diversion of oil treatment plant effluent to further treatment.
1987	Dofasco hot mill filtration plant upgrading.
1987	Dofasco diversion of biological treatment plant effluent to municipal STP.
1988	Dofasco blast furnace gas cleaning wastewater recirculation.
1987	Hamilton STP Greenhill combined sewer overflow (CSO) retention basin installed.
Strategy and Planning Completed:	
June 1986	Public consultation framework, key Stakeholders identification.

September 1987	Goals for environmental quality and uses to be restored based on jurisdictional objectives and public consultation.
December 1987	Optional remedial actions, potential implementation schedule, based on cost/benefit analyses and public consultation.
March 1988	Draft RAP with use goals, remedial actions, for agency and public review.
March 1989	Stage 1 Report

Monitoring Activities:

1987	Analysis of STP effluent for toxic contaminants (185 priority pollutants).
1987	Initiation of first phase of monitoring effluent for Iron and Steel Industry Sector under the Municipal/Industrial Strategy for Abatement (MISA) Program.
1986 - 1989	Intensive monitoring of Harbour and tributaries to establish new baseline for future monitoring and to assess impact of past remedial actions.
1989	Redesign of monitoring program for ambient water quality STP effluent, fish, wildlife, sediment, and tributaries.
1988 - 1989	Specification of effluent and process monitoring for iron and steel industry (self monitoring), under the MISA program.
1988 - ongoing	Execution of the annual and intensive monitoring schedules designated in the plans noted above.

Industrial and Municipal Sources:

1989	Established best available technology (MISA) to be applied to STPs or to industrial components of STP inputs for toxic chemical remediation, and set schedule for implementation.
1989	Establish best available technology (MISA) to be applied to the iron and steel industry for toxic chemical remediation, and set schedule for implementation.
1987 - 1988	Establish technology for ammonia treatment and

	further nutrient removal in STPs compatible with toxic chemical remediation strategy/technology and with loading targets for Harbour.
1988	Implementation of first of CSO remediation for Hamilton.
1989	Pilot plan for computer-assisted storm event control system to optimize sanitary and storm sewer operation (no sanitary sewer overflow, and treating worst components of storm runoff).
1989	Plan for completion of CSO remediation program.

Nonpoint Sources:

1989	Plan for control of suspended solids loading from major tributaries to the west end of Harbour.
1989	Refinement of estimates of tributary contributions of contaminants to Hamilton Harbour.
1989	Check on atmospheric contributions of contaminants to Hamilton Harbour.
1985	Evaluation of alternatives for cleanup of Windermere Basin.
1987	Funding remediation of contaminated sediment problem in Windermere Basin, initiating final engineering design and environmental assessment.
1989	Cleanup of Windermere Basin completed (dredging).
1989	Completion of assessment of contaminants on main Harbour sediments.

Recent Major Reports:

1985	Hamilton Harbour Technical Summary and General Management Options (MOE, 1985).
1985	Final Report: Windermere Basin Study (Envirosearch Ltd., for Windermere Basin Advisory Committee).
1986	Impact of Hamilton Harbour on Western Lake Ontario (MOE, 1986a).
1986	The Impact of Dredging and Spoils Disposal on Hamilton Harbour Fisheries: Implications for Rehabilitation. J.A. Holmes (for DFO).

Current Study Program Objectives:

1987 - 1989	Set new baseline for future remediation; assess contaminated sediments; identify fishery and wildlife rehabilitation requirements; and detail the likely impact of all possible remedial option scenarios, considering possible interactions of control technologies and aquatic ecosystems.

Public Consultation:

June 1986	Survey of views of potential Stakeholders.
July 1986	Information workshop and follow up.
September 1986	Interim report of Stakeholders to Environment Canada and Ontario MOE on goals, principles and general strategy.
October 1986	Public information meeting.
Dec. 1986 to Feb. 1987	Stakeholders discussion of issues of Windermere Basin, recreation, access, infilling of Harbour, agency programs.
May 1987	Public meeting on progress report.
March 1987	Review of progress report by Stakeholders.
June 1987	Stakeholder meeting - progress report.
July 1987	Final Stakeholders report on goals and principles.
October 1987	Stakeholder meeting - progress report.
March 1987	Stakeholder meeting - review of draft RAP.
May 1988	Public meeting on draft RAP.
October 1988	Stakeholder meeting.
1988 - 2005	Periodic public review of progress on RAP.

Future Plans:

May 1989	Stakeholder Workshop to review Stage 1 report, and to provide advice on the Preferred Options for Remedial Action.
Summer 1989	Completion of Preferred Options Report.
1989 - 1990	Negotiation for commitments and schedules.

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APPENDIX A: GLOSSARY

Acid Extractables: Organic compounds, such as phenols, that can be extracted under acidic conditions.

Adsorption: the adhesion of a substance to the surface of a solid.

Anoxic: without dissolved oxygen, or deprived of oxygen.

ARDA: Agricultural Rehabilitation and Development Directory (OMAF).

Base-neutral Extractables: Organic compounds that can be extracted under basic or neutral conditions, such as naphthalene and dichlorobenzene.

Benthos: the community of organisms living at or in the bottom of a body of water.

Biomass: the total amount, by weight, of all organisms or of a specified type of organism in a given area.

Bioturbation: the physical disturbance of sediments by burrowing and other activities of organisms.

BOD: Biological oxygen demand. The amount of oxygen necessary for the oxidation of water-bourne oxidizable compounds by the micro-organisms present in the body of water.

CDF: Confined disposal facility for dredged material.

CCIW: Canada Centre for Inland Waters.

COD: Chemical oxygen demand.

Coliforms: contaminating bacteria normally found in the gut of vertebrates and eliminated in the feces (fecal coliforms). May cause gastric ailments if ingested.

Conventional parameters: Parameters and pollutants that have been measured for many years, such as COD, phenols, cyanide, suspended sediments, nitrogen, phosphorus, sulfide, and organic carbon.

CWS: Canadian Wildlife Service (Environment Canada).

DDE: breakdown product of DDT.

Detritus: decaying plant and animal matter.

DFO: Department of Fisheries and Oceans (Federal).

Dofasco: steel industry situated on the south shore of Hamilton Harbour.

Epilimnion: surface layer of water, above the thermocline (cf.), warmer and more oxygenated than the hypolimnion (cf.).

ESA: Environmentally sensitive area.

Ether Extractables: Organic compounds that can be extracted by ether.

Euphotic Zone: the layer of a body of water down to the limits of effective light penetration for photosynthesis.

Eutrophication: having abundant nutrients which leads to excessive productivity of plant and animal matter, frequently resulting in oxygen depletion in the lower layers of a body of water.

Exceedence: when the concentration of a pollutant exceeds the water quality guideline for that molecule.

Halton Region: a political region which includes the city of Burlington and the north-east portion of the Hamilton Harbour watershed.

Hamilton-Wentworth Region: a political region which includes the city of Hamilton, Flamborough Township, and the west and south portions of the Hamilton Harbour watershed.

Heavy Metals: generic term for polluting metals such as lead, cadmium, mercury, zinc, etc. Usually does not include iron.

HHC: Hamilton Harbour Commission.

Hyperplasia: a tumour consisting of excessive tissue growth.

Hypolimnion: the deeper layer of a body of water, below the thermocline (cf.). Usually has less oxygen and is colder than the epilimnion (cf.).

IJC: International Joint Commission.

Jackson Units: a measurement of turbity determined by comparing the amount of light seen through a certain length of the sample against a series of standards.

Kjeldahl Nitrogen: total nitrogen content of a sample, determined by digesting the sample with concentrated sulfuric acid, and distilling the resultant NH_4SO_4 to produce ammonia.

Littoral Zone: a shallow area along the shore of a body of water, usually with emergent subaquatic plants.

LOI: Loss on ignition.

Macrophytes: "higher" plants, not algae.

MOE: Ontario Ministry of the Environment.

Neoplasm: tumour of abnormal tissue growth.

NWRI: National Water Research Institute (Environment Canada).

OECD: Organization for Economic Cooperation and Development.

OMAF: Ontario Ministry of Agriculture and Food.

OMNR: Ontario Ministry of Natural Resources.

Organochlorines: chlorinated organic compounds such as PCBs (cf.) and pesticides.

PAH: polyaromatic hydrocarbons, some known to be carcinogens in mammals.

Papilloma: a benign tumour, such as a polyp, on the skin.

PCB: Polychlorinated biphenyls.

Priority Pollutants: As defined by MISA (the Municipal and Industrial Strategy for Abatement), toxic chemicals that could pose a hazard to the receiving environment based on the chemical's persistence, potential to bioaccumulate, and acute and sub-lethal toxicity to organisms including humans. The list of about 125 pollutants includes heavy metals and pesticides.

RBG: Royal Botanical Gardens.

Secchi Disc Measurements: the water depth below which a black and white disc lowered into the water is invisible to the naked eye.

SOD: Sediment oxygen demand.

Stakeholder Group: a group comprising delegates from agencies, organizations, institutions, government departments, industries, and private citizen groups, all of which have an interest in Hamilton Harbour.

Stelco: steel industry on the south shore of Hamilton Harbour.

STP: sewage treatment plant.

Surficial Sediments: the top layer of sediments.

Thermocline: Abrupt change of temperature in the water column of a water body; the interface between the epilimnion (cf.) and the hypolimnion (cf.).

Volatiles: organic compounds that can readily evaporate, such as chloroform or trichloroethylene.

APPENDIX B

Data tables referred to in text. Figure 27 (page 140) shows the sampling site locations in Hamilton Harbour. Tables 24 to 26 show the concentrations of pollutants in the sediments at these sampling sites.

Figure 27

APPENDIX B.
HAMILTON HARBOUR SEDIMENT SAMPLING LOCATIONS

Table 24: Trace metals in Hamilton Harbour sediments (μg/g dry weight).

Site	Nickel	Cobalt	Chromium	Vanadium	Copper	Lead	Zinc	Arsenic
1	25	10	33	30	27	57	252	3
2	46	29	110	67	91	165	1610	16
3	49	19	140	76	102	215	2270	18
4	53	20	158	72	115	280	2600	23
5	52	24	160	76	110	265	2740	16
6	48	17	160	64	89	245	2690	21
7	31	12	66	27	23	79	950	7
8	42	20	130	67	86	195	1670	12
9	56	21	305	87	130	440	4400	27
10	49	15	150	51	64	195	2580	11
11	28	11	67	28	36	73	545	6
12	56	26	400	87	160	570	6000	28
13	53	22	335	78	113	360	4090	25
14	40	13	210	49	145	330	1695	12
15	57	21	290	87	131	400	3710	29
16	57	23	310	88	128	430	3450	29
17	60	20	320	84	129	400	3500	30
18	30	8	125	26	39	110	645	4
19	56	21	325	89	136	470	4210	33
20	56	17	400	91	149	690	6630	46
21	60	21	310	82	130	390	3470	36
22	34	13	125	45	95	150	1660	10
23	47	18	200	73	95	270	2190	24
24	53	21	360	79	140	470	5080	39
25	55	25	480	90	155	550	6060	40
26	51	23	420	80	132	430	4780	30
27	53	21	360	82	155	470	5360	38
28	53	21	360	79	158	370	3991	25
29	25	17	103	27	21	34	273	4
30	51	18	360	80	137	360	3620	25
31	53	19	400	92	155	400	4400	36
32	48	16	280	73	125	265	2910	23
33	27	11	43	36	22	36	305	2
34	32	12	145	49	58	140	1330	8
35	41	18	170	57	92	185	1850	15
36	36	15	120	51	48	88	745	14
37	37	12	490	29	85	430	3270	33
38	37	4	475	41	104	370	2960	34
39	47	4	385	75	124	325	2930	23
40	48	20	295	83	131	340	2740	29
41	39	15	98	62	136	200	1610	18
42	41	16	103	79	102	245	1820	15
43	37	14	220	54	94	200	1750	12
44	37	13	290	63	100	220	3150	13
45	49	18	400	70	160	350	2030	5
46	47	18	170	66	107	170	590	2
47	56	25	305	72	138	205	815	12

Table 25

Table 25. PAH concentrations in the surficial sediments of Hamilton Harbour (mg kg^{-1}).

Sample Site	Napthalene	Phen-anthrene	Pyrene	Benz(a) anthracene	Dibenz-anthracene	Anthracene	Benz(b) fluoranthene	Benzo(a) pyrene	Benz(ghi) perylene	Acenaph-thylene	Acenaphthene	Fluorene	Fluoranthene
1	0.08	0.42	0.76	0.26	0.08	0.08							
2	0.46	0.46	1.04	0.86	0.18	ND	0.78	0.33	0.25	0.03	0.05	0.08	0.87
3	0.65	1.17	2.05	0.92	0.27	0.18	1.94	0.87	0.95	0.10	0.09	0.20	2.24
5	0.89	1.41	2.44	1.10	0.22	0.26	2.29	1.16	1.22	0.13	0.10	0.25	2.54
10	0.14	0.28	0.51	0.20	0.06	0.06	1.43	0.73	1.37	0.14	0.11	0.29	2.97
11	2.54	3.89	5.64	2.37	0.79	0.69	0.55	0.27	0.27	0.05	0.02	0.07	0.60
15	4.24	7.37	9.99	3.93	0.83	1.36	5.46	2.89	3.02	0.44	0.27	0.87	7.06
19	3.58	4.12	6.33	2.71	0.75	0.77	8.25	4.05	4.49	0.86	0.81	1.54	12.61
21	3.35	4.40	7.23	3.25	0.99	0.92	6.77	3.52	3.58	0.54	0.30	0.96	7.88
22	4.91	14.87	27.76	10.09	1.80	4.83	7.93	4.11	4.12	0.54	0.39	1.07	9.39
23	3.04	55.39	65.31	19.39	3.69	54.02	20.99	0.51	14.89	2.05	1.35	2.87	34.85
24	5.83	9.42	11.92	4.54	1.01	2.01	29.63	17.88	17.03	6.28	6.71	12.01	81.33
36	0.33	1.32	1.56	0.69	0.10	0.27	10.32	5.62	5.30	1.72	0.86	2.45	14.93
39	7.47	15.46	34.53	17.44	3.85	6.53	1.21	0.64	0.53	0.04	0.17	0.29	1.85
41	0.05	0.52	1.04	0.50	0.07	0.20	37.11	20.23	14.87	3.68	2.88	7.77	43.25
42	1.19	2.45	4.65	2.11	0.40	0.56	1.19	0.64	0.39	0.05	0.06	0.08	1.28
43	2.26	2.57	7.59	3.03	0.86	0.66	4.86	2.59	2.33	0.33	0.40	0.59	5.47
44	2.24	2.96	6.22	2.81	0.65	0.81	7.91	4.07	4.12	0.58	1.19	0.72	8.76
46	0.16	1.70	5.74	1.94	0.45	0.33	6.85	3.57	2.77	0.37	0.87	0.88	7.12
47	0.13	1.53	4.60	1.41	0.24	0.27	4.19	2.23	2.92	0.06	0.21	0.53	6.11
							3.38	1.73	1.51	0.07	0.16	0.36	4.70

Table 26 Chlorinated organics in Hamilton Harbour sediment (mg kg^{-1} dry wt).

Site	Beta BHC	HCB	Heptachlor epoxide	Beta chlordane	Alpha chlordane	pDDE	Dieldrin	Endrin	TDE	oDDT	pDDT	Mirex	PCB
1	ND	ND	ND	ND	ND	0.009	0.005	ND	0.009	ND	0.009	ND	0.142
2	ND	ND	ND	0.012	ND	0.012	ND	ND	0.012	ND	ND	ND	0.316
3	ND	ND	ND	0.011	ND	0.015	ND	ND	0.010	ND	ND	ND	0.365
5	ND	ND	ND	0.009	ND	0.013	ND	ND	0.009	ND	ND	ND	0.376
10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.124
11	ND	ND	ND	ND	ND	0.019	ND	ND	0.019	ND	ND	ND	0.547
15	ND	ND	ND	ND	ND	0.022	ND	ND	0.016	ND	ND	ND	0.827
19	ND	ND	ND	ND	ND	0.018	ND	ND	0.014	ND	ND	ND	0.622
21	ND	ND	ND	ND	ND	0.025	ND	ND	0.015	ND	ND	ND	0.768
22	ND	ND	ND	ND	ND	0.014	0.009	ND	0.009	ND	0.026	ND	0.467
23	ND	ND	ND	ND	ND	0.007	ND	ND	0.007	ND	0.037	ND	0.154
24	ND	ND	ND	ND	ND	0.022	ND	ND	0.017	ND	ND	ND	0.391
36	ND	ND	ND	0.006	ND	0.008	ND	ND	0.012	0.004	ND	ND	0.231
39	ND	0.007	ND	ND	ND	0.011	0.011	ND	0.037	ND	0.077	ND	0.458
41	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	0.166
42	ND	ND	ND	ND	0.014	0.025	ND	ND	0.011	ND	0.022	ND	0.638
43	ND	ND	ND	ND	0.006	0.026	ND	ND	0.009	ND	0.026	ND	0.860
44	ND	ND	ND	ND	ND	0.025	ND	ND	0.006	ND	0.022	ND	0.814
46	ND	ND	ND	ND	0.014	0.031	0.010	ND	0.010	ND	0.034	ND	0.777
47	ND	ND	ND	ND	0.012	0.036	0.009	ND	0.009	ND	0.023	ND	1.296

ND Non-detectable

APPENDIX C: CURRENT REGULATORY TOOLS

1. Spill Control

The ultimate responsibility for spill cleanup lies with the polluter, but Provincial, Federal and Municipal governments are charged with ensuring spills are dealt with promptly and adequately. In general, the Canadian Coast Guard (CCG) is responsible for all spills originating from ships, and the Ontario Ministry of Environment (MOE) is the lead agency for land-based incidents. The City of Hamilton Public Works Department may assume control for spills affecting roads and storm sewers, and Environment Canada deals with spills from federal facilities and operations. Legislation requires the immediate reporting and the control and cleanup of spills. The specific requirements are stated in the Federal Shipping Act.

The Ontario Ministry of Environment operates a 24-hour Spills Action Centre for coordination of environmental emergencies. Staff pass on reports to appropriate individuals and assist on-scene response people with information. The Port of Hamilton Spill Control Group operates on a voluntary basis. It is a cooperative consisting of local industries, the Harbour Commission and the Canadian Coast Guard, each committed to share equipment and expertise during spill incidents.

2. MOE Effluent Control Orders

The steel mills are required to control discharges to the natural environment. Orders have been issued under Section 6 of the Ontario Environmental Protection Act requiring such controls. The last Orders were served upon the steel mills in 1980-81. The mills are complying with the Orders with the last items to be completed in June 1989.

3. Municipal/Industrial Strategy for Abatement (MISA)

The Municipal/Industrial Strategy for Abatement is Ontario's new control program designed to systematically reduce the discharge of toxic contaminants.

The ultimate goal of the program is the virtual elimination of persistent toxic contaminants in municipal and industrial discharges to Provincial waterways. The program was announced in 1986 by Environment Minister Jim Bradley.

MISA is a regulatory program. For each of the eight major sectors of industry and the municipal sector, two regulations will be developed. Initially, discharges will be subject to a monitoring regulation which requires the industry or municipality to identify and measure concentrations of conventional and toxic contaminants in their effluents. This information will be used to formulate Effluent Limits Regulations. Following an analysis of these data, an abatement regulation will specify allowable concentrations, as well as amounts or loadings, of toxic pollutants for each discharger.

The MISA Program is being undertaken in full consultation with Environment Canada, municipalities, industries, interest groups and the general public.

The MISA Advisory Committee is made up of independent technical and environmental experts. The purpose of the Advisory Committee is to review the draft regulations and provide advice and recommendations to the Environment Minister.

The two sectors of principal concern for Hamilton Harbour are the municipal sector and the iron and steel sector. The schedules for the monitoring phase and the phase specifying the "best available technology, economically achievable" (BATEA) are described below.

In the Iron and Steel industry, work began on the pre-regulation monitoring program in April, 1987, and the first sampling run was completed in November, 1987. A draft monitoring regulation was released for public review in February, 1989.

In the municipal sector, a regulation writing team was formed in 1988. A proposed sewer use control program was released in September 1988. It is designed to reduce the loadings of toxic contaminants to the municipal STPs. Monitoring of STPs have been designed to cover periods when chlorination is and is not being used.

The Iron and Steel Sector participants are monitoring specific water supply and waste streams. In Hamilton, DOFASCO is monitoring: 1. Biological Treatment Plant Influent, 2. Biological Treatment Plant Effluent, 3. Basic Oxygen Furnace slurry line, 4. Hot Rolling Filter Plant location, and 5. Water Supply Intake. STELCO is monitoring: 1. Hilton Works - Water Intake #1, 2. Hilton Works - Water Intake #2, 3. Filter Plant Outlet, 4. Blast Furnace Blowdown location, 5. Oil Treatment Plant Effluent, and 6. Weak Ammonia Liquor (directed to Hamilton STP). Both STELCO and DOFASCO are doing additional sampling at other locations as well.

The above documented work and schedules are based on the BATEA "track" for the MISA program. If the receiving water conditions call for more stringent controls, they will be addressed in the third phase of the MISA program.

4. Air Emission Controls

Control orders under Section 6 of the Ontario Environmental Protection Act have been issued to industries requiring reductions of emissions to air. As a result, industrial air emissions have been reduced by about 86% since 1970. Current programs to control point source emissions will be completed in June 1989.

Efforts to reduce wind-blown dust were started in the mid 1970s. As a result, extensive controls have been placed on the coal fields, and major roads within the steel mills have been paved and are frequently cleaned. As part of this program, the perimeters of the properties adjacent to the Harbour are being landscaped. This landscaping will not only reduce wind-blown dust but will also improve the appearance of the mill sites.

Fugitive emissions from the steel mills are serious problems in matters of air pollution. Their impact on water quality is uncertain.

APPENDIX D: HAMILTON HARBOUR STAKEHOLDERS GROUP

Stakeholder	Affiliation
John Aiken	The Board of Education for the City of Hamilton.
June Anderson	West Burlington Citizens Group
Boris Boyko (alt) Ray Stewart	OMOE, Central Region
Murray Charlton (alt) Tony Griffin	Burlington Sailing and Boating Club
Ben Ciprietti	Hamilton Harbour Advisory Committee
Geraldine Copps	Alderman, City of Hamilton
Peter Dawson	Citizen at Large
Don Dowie	Hamilton Beach Preservation Committee
Kathy Drewitt	Hamilton & District Chamber of Commerce
Gordon Duffus	Westinghouse Canada Inc.
Bob Edmonson (alt) Brenda Axon	Halton Region Conservation Authority
Hugh Eisler	Stelco Inc.
George Francis (alt) Phil Weller	Great Lakes Tomorrow
Don Fraser	United Steel Workers of America, Local 1005
George Gamble	J.I. Case/IHC
John Gartner	Citizen at Large
Pat Hayes-Potter	NETforce
Colin Isaacs	Pollution Probe
Bill Johnson	Councillor, Regional Municipality of Halton
Harry Joncas	Golden Horseshoe Outdoors Club Inc.
Brian Lang	Ministry of Agriculture and Food

Bruce Lawson	Burlington Chamber of Commerce
Norm Lockington (alt) Bruce Tanaka (alt) Murray Greenfield	Dofasco
Sheila May	Councillor, Township of Glanbrook
Brian McHattie (alt) Christine Bishop (alt) John Struger	Hamilton Naturalist Club
Sarah Miller	Canadian Environmental Law Association
Ken Minns	Fisheries and Oceans Canada
B. Mitchell	Macassa Boat Club
Walter Mulkewich (alt) Leo Deloyde	Alderman, City of Burlington
Anne Redish	Councillor, Town of Dundas
Peter Rice (alt) Len Simser	Royal Botanical Gardens
J. Robb (replaced J. Smith, Nov. 1988)	Mayor, Town of Flamborough
George Ryan	Burlington Golf and Country Club
Craig Selby	OMNR Cambridge
Peter Shebib	Hamilton District Labour Council
Kim Shikaze (alt) Simon Llewelyn	Environmental Protection Service, Environment Canada
Gil Simmons	Bay Residents Association
Carl Slater (replaced Don Herrow, May, 1989)	Proctor & Gamble Inc.
Edgar Smee (alt) Ken Ingham	Conserver Society of Hamilton and District
Stan Spencer (alt) Ted Gil	Regional Municipality of Hamilton-Wentworth

Mark Sproule-Jones	Professor of Urban Studies, McMaster University
John Tice	West Leander Boat Club
Chuck Towsley	Hamilton Harbour Commission
Jack Vallentyne	Great Lakes Science Advisory Board, IJC
Ben Vandenbrug	Hamilton Region Conservation Authority
Richard Walker	Ontario Federation of Agriculture
Madelyn Webb	Centre for the Great Lakes
Don Young (replaced R. Thompson, May, 1989)	Hamilton Yacht Club

Facilitator

Sally Leppard	LURA Group

APPENDIX E: EXISTING AND DEVELOPING PROGRAMS

The table following shows programs having an impact on Hamilton Harbour and the nearby ports of Lake Ontario, especially with regard to toxic chemicals. The table is derived from the Lake Ontario Toxic Management Plan Documentation.

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB. Actions in Canada				
IB1. Industrial Discharges (both direct to the Lake and tributaries).				
IB1a. Implement the Municipal-Industrial Strategy for Abatement (MISA) Program for industrial dischargers. In June 1986, the Ontario Ministry of the Environment announced "The Municipal-Industrial Strategy for Abatement" (MISA) Program. The program is being developed in consultation with Environment Canada, industries, interest groups and the general public. Joint technical committees (MOE, EC and Industrial Associations) for each sector will recommend practical and effective requirements for each regulation. Monitoring regulations for each industrial sector will be submitted for public review prior to their promulgation. In the Lake Ontario Basin there are five organic chemical industries, nine pulp and paper mills, three iron and steel mills, three petroleum refineries three metal mining and refining, two inorganic chemical facilities, two electric power generating stations and one metal casting operation. All dischargers are required to control wastes by operating treatment facilities under Certificate of Approval or Control Order.				
ii. Iron and Steel: Dofasco Stelco LASCO	Final Permit	MOE	Public notice '89 Monitoring Reg. '89 Compliance Reg. 1991-1992	Iron and steel mills are in compliance with heavy metal requirements
IB2. Indirect Industrial Discharges				
a. Ministry of the Environment Position on the Sewer Use Control Program	Adoption of Position by Municipalities	MOE, EC Municipal Engineer Association	Completed	

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
b. Revision of Ontario Water Resources Act in Environmental Protection Act and Municipal Act to provide adequate legislative basis for the Sewer Use Control Program	Revised Acts	MOE, Municipal Engineer Association	July, 1989	
c. Sewer Use Program Regulation	The Sewer Use Control Program will include: cataloguing direct dischargers monitoring and enforcement protocale developing control requirements (except BATEA)	MOE, Municipal Engineer Association	December, 1989	

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
d. Develop on a staged basis effluent limit regulation based on Best Available Technology Economically Achievable (BATEA). Regulations will first be applied to: - Fabricated Metal Products - Organic Chemicals - Waste Treatment & Recycling Industries - Primary Metal Industries Sectors	Regulations for effluent limits based on BATEA	MOE	1991-1993	

IB3. Municipal Discharges

IB3a . As part of the MISA program all municipal discharges will be subject to Limits Compliance Regulation by Dec. 1991. As shown in Appendix IV, all the Ontario sewage treatment plants are currently required to comply with controls for only the conventional parameters. There are 31 sewage treatment plant facilities in the Lake Ontario basin. All of the facilities are secondary treatment plants (activated sludge and continuous phosphorus removal).

I. <u>Municipal Plants:</u> <u>Hamilton</u> Hamilton, Burlington, Dundas	Final Permit	MOE/EC	Public notice. '89 Monitoring Reg. '89-'90 Compliance Reg. 1990-1991-1992	As part of MISA, an intensive sampling program was completed in 1987 where 40 municipal wastewater facilities were sampled (influent, effluent, sludge) for: PCBs, dioxins, PAHs, volatiles and heavy metals. These plants are: Toronto (4 facilities) York-Durham, Oakville, Clarkson, Lakeview, Hamilton, Burlington, Grimsby, Whitby, and Kingston.

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB4. Waste Disposal Sites - Active and Closed Sites				
a. Obtain site specific information, in order to assess potential hazard to humans and environment	Site specific report	MOE	On-going	- No compiled information on compliance is available. - Each landfill site is handled on a case-by-case basis as problems are discovered. - In many cases, actions constitute monitoring of the environment to determine existing or potential impact. - Reports will be used to identify actions required.
IB5. Combined Sewer Overflows				
IB5a. Plan and Construct CSO Abatement Facilities to Address CSO - Related Water Quality Violations				
ii. Develop CSO and STP abatement alternatives to reduce CSO and STP bypasses in the Regional Municipality of Hamilton-Wentworth	Sizing of CSO storage facilities to reduce CSO and STP bypass. Study will be used in a future comprehensive implementation plan to improve water quality to Hamilton Harbour	Regional Municipality of Hamilton-Wentworth Ministry of the Environment	March, 1990	
iii. Develop, install and evaluate a computerized system for reducing the number and volume of CSO	Reduced CSO being discharged to Cootes Paradise	Regional Municipality of Hamilton-Wentworth Ministry of the Environment	December, 1990	

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
iv. Construct CSO storage facility. Regional Municipality of Hamilton-Wentworth	72,000m^3 CSO storage facility. Reduces overflow to one event per year for a 2000 acre drainage area	Regional Municipality of Hamilton-Wentworth. Ministry of the Environment	Completed	

IB6. Stormwater Discharges

a. Municipalities to prepare Master Drainage Plans that include stormwater quality controls	Master Drainage Plan	Municipalities	Voluntary	Ontario has announced its "Urban Drainage Management Program for New Development". The program will be initially voluntary for three years
b. Developers to prepare stormwater management plans	Stormwater Management Plan	Developers	Voluntary	Technical guidelines for drainage design and erosion and sediment control have been released
c. Developers to include Stormwater management controls during construction of new development	Stormwater Management Works	Developers	Voluntary	Program indirectly controls toxics through control of sediment Some municipalities already have active programs

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB7. Other Nonpoint Sources				
a. Land Stewardship Program	Farmers to prepare integrated farm management plans.	OMAF	1990 - but voluntary to farmers	- Farmers must file farm management plans with OMAF to receive grant monies to carry out remedial plans.
b. Ontario Soil Cons. and Environmental Protection Assistance Program (OSCEPAP)	Improved waste management and soil erosion control on farms	OMAF, MOE	1991 - but voluntary to farmers	- MOE enhances OMAF $4.5M by $1M annually. - program to become a joint ministry program.
c. Rural Beaches	Remedial Action Plans	Conservation Authorities	CAs to participate voluntarily but must develop RAPs within 3 years of study initiation	- Agreements with Otonabee, Metro. Toronto, & Niagara Peninsula CAs presently in existence. - Program has a 10 year lifespan & is presently in year 3.
d. Abatement	Resolution of farm pollution problems	MOE Regional Staff	NONE	- MOE & OMAF have developed a set of protocols for determining inter-ministry responsibilities in resolving problems.
e. Drainage Design and Construction	Reduced sediment and erosion problems with drains	Municipalities	None - voluntary	- Inter-ministerial committee issued new guidelines for the construction of drains built under the Drainage Act.
f. Pesticide Management	1) registration of pesticides, education and licensing of applicators.	MOE	None - voluntary	- annual licensing of pesticide applicators. - routine monitoring for 54 pesticides at river mouth stations - development of fate & pathway models
	2) Food Systems 2002 for 50% reduction in pesticide use.	OMAF	2002	- Commences Apr. 1/88. - Program consists of education, delivery & research.

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB9. Spills				
a. The Ontario Ministry of the Environment investigates nature and extent of environmental damage by each spill, evaluates adequacy of clean-up, enforces legislated responsibilities imposed on dis-chargers	Every person having control of a pollutant that is spilled and every person who spills shall notify the Ministry and other persons that may be affected Cleanup of spilled materials	MOE	Ongoing	
IB10. Dredging and Dredged Material Disposal				
a. Identify all active dredging locations and open water dredged material disposal areas	Map of disposal areas	MOE	Ongoing	
b. Develop MOE sediment quality objectives and dredging and dredged spoil dis-posal guidelines to take into considera-tion biological effects	Guidelines to be applied to dredging projects	MOE	1989/1990	
c. Identify areas (hot spots) from which dredged spoil is unsuitable for open Lake disposal	Maps of hot spots	MOE	Ongoing	
d. Investigate alterna-tive disposal methods, including confined or land disposal	Identification of alternatives to open Lake disposal	MOE	Ongoing	

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB11. Solid Waste				
a. Ontario Regulation 309 for Waste Management is currently under review to establish more stringent requirements for Solid Waste Management	Stringent requirements related to standards in the location and operation of an incineration site, a dump site and sites designated for organic soil conditioning	MOE	Ongoing	
IB12. Sludge Disposal				
a. Continue MOE's program for monitoring 14 parameters (11 of which are metals) in sludge to be disposed of on agricultural land	The 14 parameters provide information about metals and nutrients added to soil in sewage sludge	MOE	Ongoing	Parameters are 11 metals, phosphorus, suspended solids, ammonium and nitrate nitrogen
b. Monitor hazardous contaminants in sludge generated from municipal facilities as part of the MISA program	Review need for standards for sludge used on agricultural lands and set standards for organic chemicals in sludge when necessary	MOE, OMAF* and MOH** (through sludge utilization committee)	Ongoing	
c. Determine if sludges comply with standards for organic contaminants for sludges used on agricultural lands		MOE, OMAF, and MOH	Ongoing	

* OMAF- Ontario Ministry of Agriculture and Food
** MOH- Ministry of Health

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB13. Ambient Water Monitoring				
IB13a. Conduct Ongoing Ambient Water Quality Monitoring				
i. Provincial Water Quality/Quantity Monitoring Network	Loadings and complete data files are provided to the IJC annually	MOE	Ongoing	32 stations scanned for 58 pesticide and industrial organic parameters, and metals in the Lake Ontario drainage basin
ii. Enhanced Tributary Monitoring Program	Loadings and complete data files are provided to the IJC annually	MOE	Ongoing	5 Lake Ontario tributaries monitored for enhanced precision of annual contaminant load estimates (40-100 event-oriented samples/stn/yr). Suspended bed sediments sampled annually for trace metals, organochloride pesticides
IB13b. Conduct Ongoing Monitoring of Biota				
i. Fish Contaminant Monitoring Program	Annual publication "Guide to Eating Ontario Sport Fish"	MOE/MNR	Ongoing	36 locations, for 22 species of fish for up to 24 parameters including PCBs, mirex, dioxin, organochlorine pesticides, mercury, heavy metals; part of the largest continuous contaminants data base on biota in the world
ii. Juvenile Fish Contaminants Surveillance	Data summaries provided to the IJC biannually. Journal paper on Lake Ontario currently under preparation	MOE	Ongoing	Contaminant residue data are available for 22 sites, and temporal trend data in excess of 10 year intervals exist for 5 Lake Ontario sites. Analytical parameters total about 60 individual compounds

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
iii. Nearshore Cladophora Monitoring	Data summaries provided to requesting agencies upon request	MOE	Ongoing	1 control site monitored for PCBs, organochlorine pesticides, chlorophenols, chlorobenzenes
iv. Long Term Sensing Sites	Interpretive Report	MOE	Ongoing Commencing 1988 First Report 3 Qtr.,1990	2 long-term sites for metals, PCBs, organochlorine pesticides, chlorophenols, chlorobenzenes

IB13c. Conduct Site-specific Studies

i. Hamilton Harbour Sediment Inputs and Bioassessment	Interpretive Report	MOE	3rd Qtr., 1990	10 sources and mouth of ship canal, for whole water, effluent and suspended sediments

IB14. Drinking Water Surveillance Program

a. Monitoring of all drinking water supplies in Lake Ontario Basin	To date 48 municipalities on Lake Ontario are being monitored for raw and treated drinking water. At each location 160 parameters are analyzed, including pesticides, organics, trihalomethanes, volatiles, chlorinated organics and dioxin and furans. Corrective actions immediately undertaken if poor quality noticed	MOE	Ongoing	The plants using Lake Ontario as a water source serve the following locations: Grimsby, Hamilton, Burlington, Mississauga (Lakeview and Lornepark), Toronto (R.L. Clark, R.C. Harris, Easterly), Oshawa, Deseronto and Belleville Raw and treated waters of each plant, at each location are tested for several conventional and priority pollutants
b. Review existing Drinking Water Standards and revise as necessary	Stringent water quality standards	MOE/EC	Ongoing	

ACTION	OUTPUT	RESPONSIBLE PARTY	DEADLINE	COMMENTS
IB. Actions in Canada				
IB1. Industrial Discharges (both direct to the Lake and tributaries).				
IB1a. Implement the Municipal-Industrial Strategy for Abatement (MISA) Program for industrial dischargers. In June 1986, the Ontario Ministry of the Environment announced "The Municipal-Industrial Strategy for Abatement" (MISA) Program. The program is being developed in consultation with Environment Canada, industries, interest groups and the general public. Joint technical committees (MOE, EC and Industrial Associations) for each sector will recommend practical and effective requirements for each regulation. Monitoring regulations for each industrial sector will be submitted for public review prior to their promulgation. In the Lake Ontario Basin there are five organic chemical industries, nine pulp and paper mills, three iron and steel mills, three petroleum refineries three metal mining and refining, two inorganic chemical facilities, two electric power generating stations and one metal casting operation. All dischargers are required to control wastes by operating treatment facilities under Certificate of Approval or Control Order. The present situation of compliance and remedial actions for these industrial discharges is shown in Appendix IV.				
ii. Iron and Steel: Dofasco, Stelco, LASCO	Final Permit	MOE	Public notice '89 Monitoring Reg. '89 Compliance Reg. 1991-1992	Iron and steel mills are in compliance with heavy metal requirements
IB2. Indirect Industrial Discharges				
a. Ministry of the Environment Position on the Sewer Use Control Program	Adoption of Position by Municipalities	MOE, EC Municipal Engineer Association	Completed	

ACTIVITY	LOCATION	[illegible]	LOCATION	COMMENTS
20. Active in Canada				
201. Industrial Wastewater Discharges of the Pulp and Paper Sector				
2010. Introduction: The Anticipated Industrial Wastewater The Canadian [illegible] Pulp and Paper Industry in June 1976, the Director-General of the Environment published "The Anticipated Industrial Wastewater Sector (ISWS) Program. The purpose of this paper is to [illegible] Canada, [illegible] groups and the general public. [illegible] 20 and [illegible] the pulp and paper sector will increase [illegible] and effluent [illegible] industrial sector will be [illegible] and fine organic chemical [illegible] [illegible] and the metal mining industry [illegible] industrial discharges to be [illegible]				
11. Iron and Steel				
Dofasco Hamilton Ontario	Plant Effluent	[illegible]	Water Quality Act 1968 Continuing Obj. 1974 Compliance Obj. (1971-1974)	Iron and steel mills are in [illegible] with heavy metal [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Remedial Action Plan
Plan d'Assainissement

Canada Ontario

Canada-Ontario Agreement Respecting Great Lakes Water Quality
L'Accord Canada-Ontario relatif à la qualité de l'eau dans les Grand Lacs